International Lead Association

thinkstep

Life Cycle Assessment of Primary Lead Production Mix

Europe and North America

On behalf of ILA

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On behalf of thinkstep AG and its subsidiaries

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List of Acronyms

AP	Acidification Potential
CML	Centre of Environmental Science at Leiden
EoL	End-of-Life
EP	Eutrophication Potential
GaBi	Ganzheitliche Bilanzierung (German for holistic balancing)
GHG	Greenhouse Gas
GWP	Global Warming Potential
ILA	International Lead Association
ILCD	International Cycle Data System
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
PED	Primary Energy Demand
PGM	Platinum Group Metals
QSL	Queneau-Schuhmann-Lurgi (smelting process)
ts	thinkstep AG

Glossary

Life Cycle

A view of a product system as "consecutive and interlinked stages … from raw material acquisition or generation from natural resources to final disposal" (ISO 14040:2006, section 3.1). This includes all material and energy inputs as well as emissions to air, land and water.

Life Cycle Assessment (LCA)

"Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 14040:2006, section 3.2)

Life Cycle Inventory (LCI)

"Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle" (ISO 14040:2006, section 3.3)

Life Cycle Impact Assessment (LCIA)

"Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product" (ISO 14040:2006, section 3.4)

Life Cycle Interpretation

"Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations" (ISO 14040:2006, section 3.5)

Functional Unit

"Quantified performance of a product system for use as a reference unit" (ISO 14040:2006, section 3.20)

Allocation

"Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems" (ISO 14040:2006, section 3.17)

Closed-loop and Open-loop Allocation of Recycled Material

"An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties."

"A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials."

(ISO 14044:2006, section 4.3.4.3.3)

Foreground System

“Those processes of the system that are specific to it … and/or directly affected by decisions analysed in the study.” (JRC, 2010, p. 97) This typically includes first-tier suppliers, the manufacturer itself and any downstream life cycle stages where the manufacturer can exert significant influence. As a general rule, specific (primary) data should be used for the foreground system.

Background System

“Those processes, where due to the averaging effect across the suppliers, a homogenous market with average (or equivalent, generic data) can be assumed to appropriately represent the respective process … and/or those processes that are operated as part of the system but that are not under direct control or decisive influence of the producer of the good….” (JRC, 2010, pp. 97-98) As a general rule, secondary data are appropriate for the background system, particularly where primary data are difficult to collect.

Critical Review

“Process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment” (ISO 14044:2006, section 3.45).

Gate-to-gate

Primary or secondary data representing all direct inputs and outputs from an industry process, does not considers the upstream processes needed to account the environmental impacts from the extraction of raw materials and/or the production of intermediate products needed to complete the product system.

Cradle-to-gate

Approach which addresses the environmental aspects and potential environmental impacts (e.g. use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production until the product is ready to continue its life cycle (as intermediate product, use phase, etc.).

1. Goal of the Study

The goal of the study is to assess the life cycle environmental profile of primary lead production mix in Europe and North America. This study provides a cradle-to-gate weighted average Life Cycle Inventories (LCI) and environmental impact data for European and North American lead production mix via primary route. The study has been conducted according to ISO 14040/44, the international standards on Life Cycle Assessment (LCA).

The results of the study will be used by the International Lead Association (ILA) to improve its understanding of the environmental impact of lead production from cradle-to-gate and will promote continuous improvement in the environmental sustainability of primary lead products. The data generated from the study will help ILA to respond to demands from various stakeholders for reliable, quantified environmental data. Finally, the study will enable ILA to continue to participate and contribute to a range of sustainability initiatives and the ongoing methodological discussions within LCA and related disciplines.

The intended audience for this study includes ILA, lead producers, legislators, customers, environmental practitioners and non-governmental organizations.

The results of the study are not intended to be used in comparative assertions intended to be disclosed to the public. It is acknowledged that the data provided might be used by others for comparative assertions. Such comparisons should only be made on a product system basis and be carried out in accordance with the ISO 14040/44 standards, including an additional critical review by a panel (ISO 14040:2006 and ISO 14044:2006).

A third party critical review of the study according to ISO 14040, ISO 14044 and ISO/TS 14071 has been carried out by Matthias Finkbeiner from Technical University Berlin[1]. The final review statement is documented in Annex A.

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[1] The reviewer acts and was contracted as an independent expert, not as a representative of his affiliated organization.

2. Scope of the Study

The following sections describe the general scope of the project to achieve the stated goals. This includes, but is not limited to, the identification of specific product systems to be assessed, the product function(s), functional unit and reference flows, the system boundary, allocation procedures, and cut-off criteria of the study.

2.1. Product System(s)

This study assesses the environmental impacts associated with primary lead production mix from cradle-to-gate for Europe and North America. The refined lead product has a purity of 99.00 to 99.99% and can be used for a variety of applications across the construction, automotive and electronics sectors as well as being used as an alloying metal. The study results are representative of primary refined lead produced by lead manufacturers in Europe and North America. The reference year for the data is 2015. The participating companies represented 86% of primary production in Europe and North America over the same period. Results are presented as a mass weighted average (or mass weighted arithmetic mean) calculated based on the production output for each company for the reference year 2015.

2.2. Product Function(s) and Functional Unit

The functional unit is the reference value for which the results of the study are calculated. Generally, a functional unit should reflect the function provided by the product being assessed. However, in this study the primary refined lead product is an intermediate product that may be used for a wide variety of different applications. As these applications are beyond the scope of this report, a cradle-to-gate study is the appropriate choice. Consequently, the following mass-based functional unit and identical reference flow has been designated for this study:

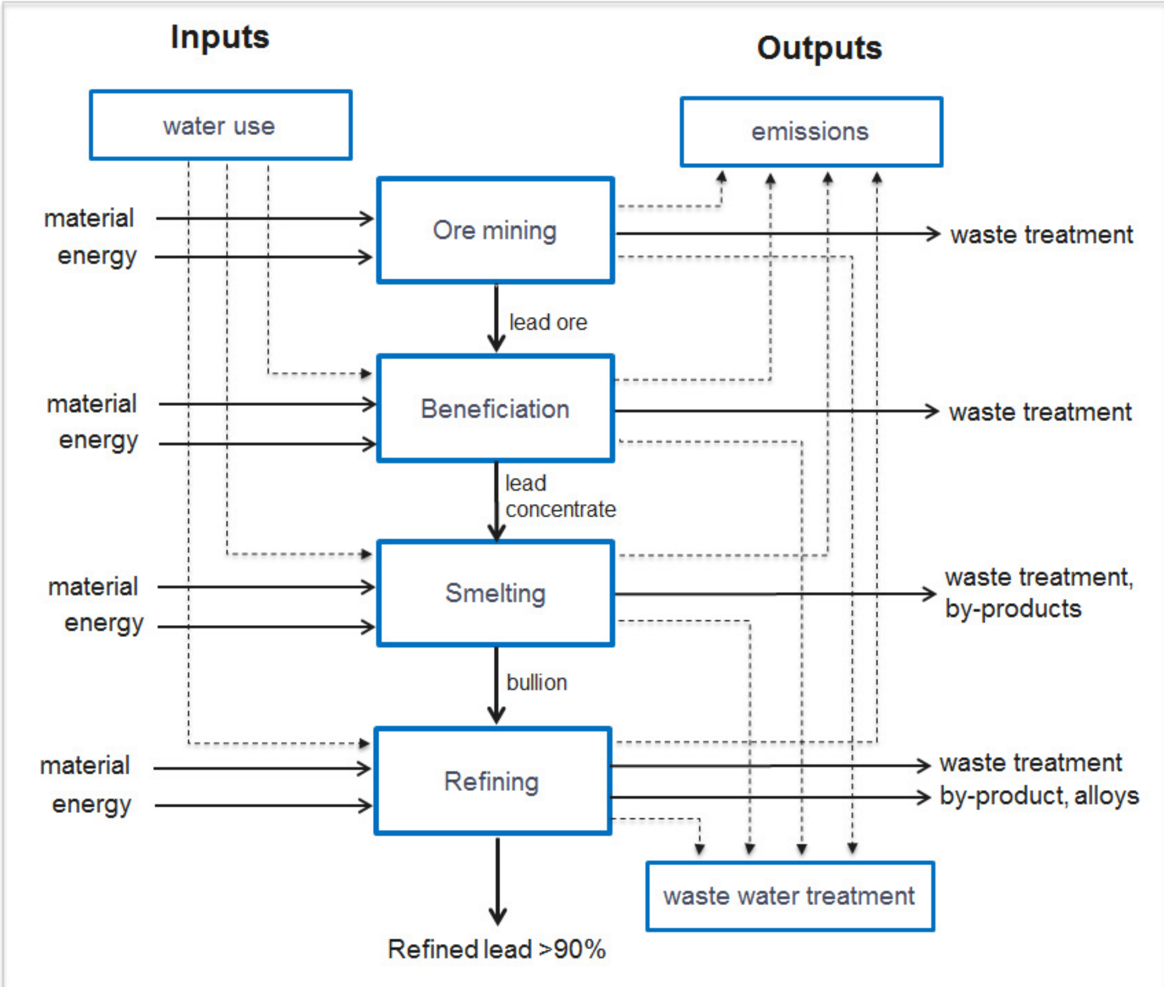
1 kg of refined lead (99.00 – 99.99%) at the factory gate

This functional unit is consistent with the study's goals to calculate the environmental impact of primary lead product from cradle-to-gate. This functional unit is also consistent with the goal of providing data to LCA practitioners and other stakeholders, which is often provided on a mass basis with a cradle-to-gate system boundary. The functional unit covers a purity range of 99.00 – 99.99%. This range is small and well within the uncertainties of LCA data. As an alternative, the purity level could have been fixed for the functional unit and the different purities of different production sites could have been adapted via slightly different reference flows. As the resulting differences would have been below 1%, such corrections were not applied for simplicity reasons.

No alternative product systems or functional units are considered. Allocation has been used to exclude the impacts of by-products generated during primary lead production mix from the lead LCI generated in this study (see section 2.4).

2.3. System Boundary

This study considers the cradle-to-gate production of primary refined lead. That is, it considers impacts associated with the extraction of resources from nature (e.g. through mining or forestry) through to the point at which the refined product leaves the factory gate. For the primary route, the impact associated with the mining of lead ore is considered. Table 2-1 shows the major process steps considered within the system boundaries. Note that not all processes will apply to every manufacturer or processing route. Figure 2-1 show the system boundaries considered in this study for the primary route.



Cradle-to-gate system

Figure 2-1: System boundary

Table 2-1: General system boundaries

Included	Excluded
✓ Mining (underground or open cast) ✓ Beneficiation ✓ Transport of ore and concentrate ✓ Sintering ✓ Smelting (Blast furnace/QSL/Rotary) ✓ Refining ✓ All associated energy and fuels ✓ Auxiliary materials used onsite ✓ All relevant water inputs and outputs ✓ On-site production emissions to air ✓ On-site water treatment and water emissions ✓ Overburden, tailings and other mining wastes are deposited onsite ✓ Treatment of wastes including leaching from refining and waste water treated onsite.	× Packaging × Transport of fuels/auxiliary materials to site × Transport to customer × Use stage × End-of-life × Production of capital equipment and infrastructure

By-products of primary lead production such as zinc, silver, platinum group metals (PGM) and lead alloys, have been allocated using mass metal content allocation as described in section 2.4. Packaging used for transporting products to customer has been excluded. However, given the low packaging requirements for refined lead, this exclusion is not expected to have a significant effect on the results.

Sintering of fine particles of lead concentrate prior to smelting has not been presented separately, since it is not a common practice for all participating companies and if done it is considered under the smelting process step.

Transport of fuels/auxiliary materials has been excluded due to a lack of data but is expected to be significantly smaller than the impacts of transport of ore and concentrate. Production and maintenance of capital goods have also been excluded from the study. It is expected that these impacts will be negligible compared to the impacts associated with running the equipment over its operational lifetime. As this is a cradle-to-gate study, transport to customer, the use stage and end-of-life of lead lie outside the system boundary.

2.3.1. Time Coverage

The intended time reference for the study is 2015. Data collected from the ILA member companies participating in the study relate to this year. The results of the study are relevant for 2017 (the year in which the study has been conducted) and are expected to be relevant until such time as there is a significant change in the production mix, energy mix or manufacturing technology.

2.3.2. Technology Coverage

This study assesses the cradle-to-gate impacts of primary lead production based on the current European and North American technology mix and with a purity of 99.00 – 99.99%. Primary site data have been gathered from ILA's European and North American members to ensure that the model used to assess the environmental impact of lead is technologically representative for each stage of the lead production process.

2.3.3. Geographical Coverage

The results of this study are representative of primary lead produced in Europe and North America. As the lead production is not uniformly distributed in these regions, the upstream data on energy and fuels have been based on the relevant country of production for each production site with country-specific data used wherever possible.

For European production, regional EU-28 data has been used where national data are unavailable. For the North American production specific country mixes have been used, e.g. Canada. These data have been combined with primary data gathered from manufacturing sites to ensure that the data and models are representative.

2.4. Allocation

2.4.1. Multi-input Allocation

Multi-input allocation follows the requirements of ISO 14044, section 4.3.4.2, with the allocation rule most suitable for the respective process step applied within the process. No foreground processes required multi-input allocation, however, multi-input allocation was applied for waste processes including energy recovery, landfill and waste water treatment. The allocation rules applied to these processes are described in greater detail in section 2.4.3.

2.4.2. Multi-output Allocation

Multi-output allocation generally follows the requirements of ISO 14044, section 4.3.4.2. When allocation was necessary during the data collection phase, the allocation rule most suitable for the respective process step was applied and documented.

The production of lead results in a number of by-products. According to ISO 14044, allocation should be avoided where possible by using system expansion to include the additional functions of the by-products. However, given the large number of potential by-products and the complex refining processes involved, this is not practical for the majority of lead by-products. Consequently, allocation has been used to distribute the environmental impacts of the production processes to the various by-products.

In this study, mass allocation on the basis of metal content has been applied to all by-products (including silver in the primary route) at the point at which these metals are separated from lead and sent for further processing. This is consistent with the previous ILA LCA study conducted in 2010, which allocated lead and lead alloys based on mass. As lead and lead alloys in the study were both 100% metal, this is equivalent to allocating by metal content. Recently, the metals sector, led by various industry associations including ILA ((PE International, 2014), have made efforts to harmonise LCA methodologies across the sector. One of the outputs of this effort suggests that mass be used as the preferred allocation method for base metals (including lead) as mass is a consistent physical property and allows for geographical and temporal consistency. The mass allocation has been chosen over an economic allocation as a conservative approach. In addition, the difference in market value between the metals is generally small for base metals.

Where secondary lead material is produced during a process step but stored on site or sold, allocation is based on metal content. These secondary materials were defined, and reported as, considering a lead content range i.e. low secondary material (<10%), medium secondary material (>10% - <80%) and high secondary material (>80%). A conservative lead content of 1% for the low secondary material, 10% for the medium secondary material, and 80% for the high secondary materials respectively was assumed to apply the allocation.

Allocation of background data (energy and materials) taken from the GaBi 2017 databases is documented online (thinkstep, 2018).

2.4.3. End-of-Life Allocation

End-of-Life allocation generally follows the requirements of ISO 14044, section 4.3.4.3.

Landfilling (avoided burden approach): In cases where materials are sent to landfills, they are linked to an inventory that accounts for waste composition, regional leakage rates, landfill gas capture as well as utilisation rates (flaring vs. power production). A credit is assigned for power output using the regional grid mix.

Material recycling (cut-off approach): Any open metal secondary materials inputs into manufacturing remain unconnected (burden free). The system boundary at end of life is drawn after scrap collection, which generates an open scrap output for the product system. The dismantling of these EoL lead materials and collection thereof is not considered in this cradle-to-gate study. If a product is made out of a mix of primary and secondary Pb metal, e.g. batteries, the environmental impacts of primary metal production are attributed to this product. In its EoL stage (after recycling) the credits should be given only to the portion of primary metal used in the product and not to the amount corresponding to the secondary material input.

Waste water treatment (avoided burden): Waste water streams are linked to industry-average inventories. These inventories allocate impacts to water on a mass basis. Users are able to select relevant inventories for the region or country in question. These inventories capture the impacts related to waste water treatment for the country/region and take into account the proportion of dry sludge that is used as fertilizer, incinerated, landfilled or sent for composting. Credits are assigned for the sludge used as a fertilizer (where it replaces synthetic fertilizers), for electricity produced from the incineration of sludge and for electricity produced from landfill gas.

2.5. Cut-off Criteria

No cut-off criteria have been defined for this study. As summarized in section 2.3, the system boundary has been defined based on relevance to the goal of the study. For the processes within the system boundary, all available energy and material flow data have been included in the model. In cases where no matching life cycle inventories are available to represent a flow, proxy data have been applied based on conservative assumptions regarding environmental impacts.

2.6. Selection of LCIA Methodology and Impact Categories

The impact assessment categories and other metrics considered to be of high relevance to the goals of the project are shown in Table 2-2 and Table 2-3.

Various impact assessment methodologies are applicable for use including CML (Guinée, et al., 2002), ReCiPe (Goedkoop, et al., 2009), and selected methods recommended by the ILCD (ILCD, 2011). This assessment is predominantly based on the CML impact assessment methodology framework (CML 2001 update January 2016). CML characterisation factors are applicable to the European and can be applied in the North American context too, are widely used and respected within the LCA community, and required for Environmental Product Declarations under EN 15804. The Product Environmental Footprint (PEF) method (European Union, 2013) which is being developed by the European Commission and is currently in the pilot phase requires compliant assessments to take account of 15 LCIA methods. The use of a predefined list of impact categories is aimed at driving comparability between assessments of different products. Given the likely importance of PEF for European businesses in the future, these methods were considered for inclusion in this study. However, a number of the methods are currently not considered to be very mature (Lehmann, Bach, & Finkbeiner, 2016) and remain either in revision or awaiting update. Given these issues, in this study the CML impact categories are favoured as these are well-established and remain the impact methodologies favoured by the metals industry for the European context (PE International, 2014).

For impact categories where CML characterisation factors are not available (e.g. land use transformation) or where they are not considered to be the most current or robust (e.g. global warming potential, human- and eco-toxicity), alternative methods are used and are described in more detail below.

Global warming potential and non-renewable primary energy demand were chosen because of their relevance to climate change and energy efficiency, both of which are strongly interlinked, of high public and institutional interest. The global warming potential impact category used is based on the current IPCC characterisation factors taken from the 5th Assessment Report (IPCC, 2013) for a 100 year timeframe (GWP100) as this is currently the most commonly used metric. Primary energy demand is included as a measure of the total cradle-to-gate energy consumption for the product system.

Eutrophication, acidification, and photochemical ozone creation potentials were chosen because they are closely connected to air, soil, and water quality and capture the environmental burdens associated with commonly regulated emissions such as NO_x, SO_2, VOC, and others. These methods are based on the CML impact category method.

Additionally, this project includes measures of toxicity, particulate matter/respiratory inorganics and land use transformation. These categories are all subject to significant uncertainties and criticisms and are presented for internal use only in Annex C:

Human and ecotoxicity are assessed employing the USEtox™ characterisation model USEtox™ is currently the best-available approach to evaluate toxicity in LCA and is the consensus methodology of the UNEP-SETAC Life Cycle Initiative. The precision of the current USEtox™ characterisation factors is within a factor of 100–1,000 for human health and 10–100 for freshwater ecotoxicity (Rosenbaum, et al., 2008). This is a substantial improvement over previously available toxicity characterisation models, but still significantly higher than for the other impact categories noted above. Given the limitations of the characterisation models for each of these factors, results are not to be used to make comparative assertions.

The particulate matter/respiratory inorganics impact category measures the effect on human health of selected particulate matter/ inorganic emissions. For European and North American lead production mix, this impact category is based on the method recommended by the ILCD and the European Commission (ILCD 2011). The method in question is based on the RiskPoll method (Rabl & Spadaro, 2004) and assesses the effect on human health of ammonia, carbon monoxide, NOx, SOx, dust and particulate matter.

Impacts associated with land use (occupation) and conversion (transformation) are assessed using the impact category recommended by the ILCD and the European Commission (ILCD 2011), developed by Milà i Canals et al. (Mila i Canals, Romanya, & Cowell, 2007). Land occupation considers the effects of the land use, the amount of area involved and the duration of its occupation (changes in quality multiplied by area and duration). Land transformation considers the extent of changes in land properties and the area affected (changes in quality multiplied by the area).

Ozone depletion potential has not been included in this study. The Montreal Protocol on Substances that Deplete the Ozone Layer was implemented in 1989 (UNEP, 1989) with the aim of phasing out emissions of ozone depleting gases. The protocol has been ratified by all members of the United Nations – an unprecedented level of international cooperation. With a few exceptions, use of CFCs, the most harmful chemicals have been eliminated, while complete phase out of less active HCFCs will be achieved by 2030. As a result, it is expected that the ozone layer will return to 1980 levels between 2050 and 2070. In addition, no ozone-depleting substances are emitted in the foreground system under study. For these reasons, ozone depletion potential is not considered in this study.

Abiotic depletion of elemental resources assesses the availability of natural elements in minerals and ores. Abiotic depletion of elements may be calculated based on either ultimate resources, which is a measure of the total crustal abundance of an element or based on reserves which is a measure of what is economically feasible to extract. These two approaches lead to vastly different results and neither is widely accepted by the metals industry (PE International, 2014). Further issues arise with the definition of available resources/reserves, leading to significantly different results for different methods as acknowledged in the ReCiPe methodology report (Goedkoop, et al., 2009). The method from CML (Guinée, et al., 2002) that was originally recommended for use in the EU's Product Environmental Footprint initiative uses reserve base as characterized by the US Geological Survey as a measure of elemental/mineral availability. However, the USGS has stopped updating reserve as of 2009 and consequently these figures are out of date and do not take account of recent changes in reserves which are subject to significant variation as demand for resources rises or falls (Drielsma, et al., 2016). Given the methodological issues and uncertainty related to ADP of elements at the present time, this method has not been included in this study.

Table 2-2: Impact category descriptions

Impact Category	Description	Unit	Reference
Global Warming Potential (GWP100)	A measure of greenhouse gas emissions, such as CO_2 and methane. These emissions are causing an increase in the absorption of radiation emitted by the earth, increasing the natural greenhouse effect. This may in turn have adverse impacts on ecosystem health, human health and material welfare.	kg CO_2 equivalent	(IPCC, 2013)
Eutrophication Potential (EP)	Eutrophication covers all potential impacts of excessively high levels of macronutrients, the most important of which nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In aquatic ecosystems increased biomass production may lead to depressed oxygen levels, because of the additional consumption of oxygen in biomass decomposition.	kg PO_4^{3-} equivalent	(Guinée, et al., 2002)
Acidification Potential (AP)	A measure of emissions that cause acidifying effects to the environment. The acidification potential is a measure of a molecule's capacity to increase the hydrogen ion (H^+) concentration in the presence of water, thus decreasing the pH value. Potential effects include fish mortality, forest decline and the deterioration of building materials.	kg SO_2 equivalent	(Guinée, et al., 2002)
Photochemical Ozone Creation Potential (POCP)	A measure of emissions of precursors that contribute to ground level smog formation (mainly ozone O_3), produced by the reaction of VOC and carbon monoxide in the presence of nitrogen oxides under the influence of UV light. Ground level ozone may be injurious to human health and ecosystems and may also damage crops.	kg C_2H_4 equivalent	(Guinée, et al., 2002)
Human toxicity Eco-toxicity	A measure of toxic emissions which are directly harmful to the health of humans and other species.	Comparative toxic units (CTU_h, CTU_e)	(Rosenbaum, et al., 2008)
Particulate matter/respiratory inorganics	A measure of the risk to human health associated with particulate matter and selected inorganic emissions	kg PM 2.5 equivalent	(Rabl & Spadaro, 2004)

Land use midpoint v.1.06	Land occupation considers the effects of the land use, the amount of area involved and the duration of its occupation. Land transformation considers the extent of changes in land properties and the area affected.	kg C deficit eq	(Mila i Canals, Romanya, & Cowell, 2007)

Table 2-3: Other environmental indicators

Indicator	Description	Unit	Reference
Primary Energy Demand (PED)	A measure of the total amount of primary energy extracted from the earth. PED is expressed in energy demand from non-renewable resources (e.g. petroleum, natural gas, etc.) and energy demand from renewable resources (e.g. hydropower, wind energy, solar, etc.). Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account.	MJ (lower heating value)	(Guinée, et al., 2002)

It shall be noted that the above impact categories represent impact *potentials*, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) actually follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the functional unit (relative approach). LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

Due to their subjective and uncertain nature, no normalization, no grouping or cross-category weighting has been applied. Instead, each impact is discussed in isolation, without reference to other impact categories, before making final conclusions and recommendations.

2.7. Interpretation to Be Used

The results of the LCI and LCIA have been interpreted according to the Goal and Scope. The interpretation addresses the following topics:

- Identification of significant findings, such as the main process step(s), material(s), and/or emission(s) contributing to the overall results
- Evaluation of completeness, sensitivity, and consistency to justify the exclusion of data from the system boundaries as well as the use of proxy data.
- Conclusions, limitations and recommendations

2.8. Data Quality Requirements

The data used to create the inventory model shall be as precise, complete, consistent, and representative as possible with regards to the goal and scope of the study under given time and budget constraints.

- Measured primary data are considered to be of the highest precision, followed by calculated data, literature data, and estimated data. The goal is to model all relevant foreground processes using measured or calculated primary data.
- Completeness is judged based on the completeness of the inputs and outputs per unit process and the completeness of the unit processes themselves. The goal is to capture all relevant data in this regard.
- Consistency refers to modelling choices and data sources. The goal is to ensure that differences in results reflect actual differences between product systems and are not due to inconsistencies in modelling choices, data sources, emission factors, or other artefacts.
- Reproducibility expresses the degree to which third parties would be able to reproduce the results of the study based on the information contained in this report. The goal is to provide enough transparency with this report so that third parties are able to approximate the reported results. This ability may be limited by the exclusion of confidential primary data and access to the same background data sources.
- Representativeness expresses the degree to which the data matches the geographical, temporal, and technological requirements defined in the study's goal and scope. The goal is to use the most representative primary data for all foreground processes and the most representative industry-average data for all background processes. Whenever such data is not available (e.g., no industry-average data available for a certain country), best-available proxy data is employed.

2.9. Type and format of the report

In accordance with the ISO requirements (ISO, 2006) this document aims to report the results and conclusions of the LCA completely, accurately and without bias to the intended audience. The results, data, methods, assumptions and limitations are presented in a transparent manner and in sufficient detail to convey the complexities, limitations, and trade-offs inherent in the LCA to the reader. This allows the results to be interpreted and used in a manner consistent with the goals of the study.

It is intended that the results of the study will be made available to a wider audience through the ILA website and it is the intention that the life cycle inventories will be made available to users of the GaBi LCA software through the GaBi professional database.

2.10. Software and Database

The LCA model has been created using the GaBi Professional LCA Software system for life cycle engineering, developed by thinkstep AG. The GaBi 2017 LCI database provides the Life Cycle Inventory data for most of the raw and process materials obtained from the background system.

2.11. Critical Review

In accordance with ISO 14044 section 6.2 and ISO/TS 14071, a critical review of this study has been undertaken by Matthias Finkbeiner from Technical University Berlin, Germany to ensure conformity with ISO 14040/44. He was not engaged or contracted as official representative of his organization but acted as independent expert reviewer. The critical review of the external expert was performed after the completion of the goal and scope definition and after completion of the study report. The analysis and the verification of software model and individual datasets are outside the scope of this review.

The Critical Review Statement can be found in Annex A. The Critical Review Report containing the comments and recommendations by the independent expert(s) as well as the practitioner's responses is available upon request from the study commissioner in accordance with ISO/TS 14071.

3. Life Cycle Inventory

3.1. Data Collection Procedure

Primary data were collected using an online tool from thinkstep called the LCA Hub. The LCA Hub improves the data collection by automating the transfer of data from spreadsheets into the GaBi software. Customised data collection templates were created in the LCA Hub and customised Excel spreadsheets were also created. Data providers accessed the LCA hub using a login and entered the requested information in intuitive, customised templates. Where data providers preferred to use the Excel spreadsheets, a central data collector from ILA inserted data into the LCA Hub. Upon receipt, each questionnaire was cross-checked for completeness and plausibility using mass balance, stoichiometry, as well as internal and external benchmarking. If gaps, outliers, or other inconsistencies occurred, thinkstep engaged with the data provider to resolve any open issues.

3.2. Participating Companies

The following companies and locations participated in the assessment.

Table 3-1: Primary lead production mix participating companies

Country	Main Process steps	Company
Bulgaria	Smelting / refining	KCM
United Kingdom	Refining	Britannia Refined Metals
Germany	Smelting / refining	Berzelius Metall
	Smelting / refining	Aurubis Hamburg
	Smelting / refining	Recylex
Alaska Canada	Mining, beneficiation, smelting / refining	Teck
Portugal	Mining / beneficiation	Lundin A
Sweden	Mining / beneficiation	Lundin B
	Smelting / refining	Boliden Mineral
Australia	Mining / beneficiation	South32

3.3. Primary Route

3.3.1. Overview of Product System

Figure 2-1: System boundary shows the flow diagram, and individual unit process, considered in the primary route for the production of refined lead. These process steps represent the foreground system for which data was collected. A description of the individual unit processes (shown in blue) are given further below.

3.3.2. Description of Unit Processes

Mining

It is extremely rare that lead is found in its natural form as lead metal. As in the case of most metals, lead occurs with other elements, such as sulphur and oxygen. The most important ore (suitable for metal extraction) is galena (lead sulphide, PbS). Other ores include cerrusite (lead carbonate, PbCO3) and anglesite (lead sulphate, PbSO4). Lead rich minerals are frequently found with other metals, particularly silver, zinc, copper, and, occasionally, gold. As such, lead is also a co-product of zinc, copper and silver production.

Beneficiation/Ore preparation

The first step in primary lead production is the separation of the lead-rich ore from other materials. Flotation is the modern method of ore concentration, allowing lead to be separated from other materials. The ore mixture is ground into very small particles, and then made into a suspension or pulp by adding water and other chemicals. Air is then blown into the suspension, and the addition of frothing agents allow for a stable froth to form on the surface. Other additions can then make mineral components either sink to the bottom, or attach to the froth at the top, as the process requires.

Smelting

The next stage in primary lead production is the smelting process. Primary lead smelting focuses on the conversion of lead concentrates, complex secondary materials, and often some lead-acid battery scrap into crude lead bullion that requires further refining, see Table 3-2 for the classification of these materials. There are two pyrometallurgical processes available for the production of lead from lead sulphide or mixed lead and zinc sulphide concentrates. These are smelting in the blast furnace or imperial smelting furnace, or by direct smelting. Direct smelting – in rotary furnaces - is the more common route for primary lead production.

Table 3-2: General classification of lead materials into smelter

<table>
<tr><th>Material name</th><th>Definition</th></tr>
<tr><td>EoL material with low content of Pb (<10%)</td><td rowspan="2">coming from End of Life products e.g. Pb sheet (excluding Pb batteries)</td></tr>
<tr><td>EoL material with high content of Pb (>80%)</td></tr>
<tr><td>Secondary material with low content of Pb (<10%)</td><td rowspan="3">going to / coming from other industrial process e.g.: slag, dross, flue dust, ashes, sludge, slime, solder, matte</td></tr>
<tr><td>Secondary material with medium content of Pb (>10% <80%)</td></tr>
<tr><td>Secondary material with high content of Pb (>80%)</td></tr>
<tr><td>Internal lead material (internal recovery)</td><td>going to / coming from other process step e.g. flue dust</td></tr>
<tr><td>Waste to recovery</td><td>non-metallic e.g. plastic, used oil, etc.</td></tr>
</table>

Refining and Alloying

The next stage in lead production is refining of the lead bullion obtained from the smelting process. The refining step produces pure commercial lead metal from the lead bullion, and in some cases to separates other valuable metals, considered impurities, into their most valuable marketable form. The two main refining routes used are pyrometallurgical and electrolytic. Alloying of refined lead with other metals to give a desired composition also occurs at this stage.

Water and Emissions to Water

All site water is encompassed in a single stage, rather than being divided between processes. This includes all inputs and outputs of water to the facility, along with the energy and auxiliary materials required for on-site water treatment. While some sites release treated water and emissions to the local watershed, others send it on to further treatment at the municipal water treatment facility.

Emissions to Air

Site-wide emissions to air, most specifically those from smelting and refining, are also included in a single stage rather than being assigned to their respective processes. Some sites were able to provide fuel combustion emissions, in which case those emissions are included in this stage.

3.3.3. Gate-to-gate data

The gate-to-gate unit process data represents all materials and fuels entering the site, all products leaving the site and all emissions directly arising from on-site activities, including on-site fuel combustion. The following dataset is the weighted average of the member companies participating in this study, before allocation is applied.

Table 3-3: Gate-to-gate data for the mining and beneficiation* of lead ore per 1 kg refined lead from primary producers

Inputs	Unit	Quantity
Electricity	MJ	2.57E-01
Ore mined	kg	1.26E+01
Aluminium oxide (alumina)	kg	2.83E-03
Aluminium sulphate	kg	6.20E-03
Carboxymethylcellulose (Sodium)	kg	2.34E-03
Copper sulphate	kg	2.10E-03
Diesel	kg	2.87E-02
Explosives	kg	8.07E-03
Flocculant	kg	2.10E-05
Lime	kg	6.17E-03
Liquefied petroleum gas	kg	7.97E-04
Lubricant	kg	8.44E-04
Methyl Isobutyl Carbinol	kg	2.82E-05
Natural gas	kg	1.89E-04
Sodium cyanide	kg	3.98E-05
Sodium hydroxide	kg	1.64E-04
Sodium sulphate	kg	5.57E-03
Steel	kg	1.95E-03
Sulphuric acid	kg	1.92E-02
Tires	kg	4.27E-05
Xanthate	kg	3.37E-04
Zinc sulphate	kg	7.66E-04
Outputs	**Unit**	**Quantity**
Lead concentrate	kg	6.21E-01
Carbon dioxide to air	kg	2.90E-02
Carbon monoxide to air	kg	4.17E-05

Dust (PM2.5) to air	kg	4.69E-07
Hazardous waste (unspecified)	kg	2.23E-06
Hazardous waste for incineration	kg	4.80E-06
Hazardous waste for land-filling	kg	3.65E-02
Methane to air	kg	1.59E-06
Nitrogen oxides to air	kg	4.38E-04
Nitrous oxide (laughing gas) to air	kg	1.24E-06
NMVOC (unspecified) to air	kg	5.06E-07
Non-hazardous waste for land-filling	kg	9.74E+00
Overburden (deposited)	kg	1.44E+00
Scrap tires	kg	1.41E-02
Sulphur dioxide to air	kg	2.19E-05
Tailings (deposited)	kg	1.05E-03
Waste for recovery (unspecific)	kg	5.12E-03
Waste for recovery (used oil)	kg	3.44E-06
Waste to landfill (unspecified)	kg	8.27E-05

*The gate-to-gate data for mining and beneficiation have been aggregated to ensure data confidentiality

Table 3-4: Gate-to-gate data for the smelting process per 1 kg refined lead from primary producers

Inputs	Unit	Quantity
Electricity	MJ	2.05E+00
Thermal energy from natural gas	MJ	1.52E+00
Calcium hydroxide	kg	2.22E-03
Coal	kg	9.99E-02
Coke	kg	1.67E-01
EoL material with high content of Pb (>80%)	kg	5.21E-01
EoL material with low content of Pb (<10%)	kg	2.72E-02
Glass	kg	1.45E-02
Internal lead material (internal recovery)	kg	4.05E-01
Iron oxide	kg	5.40E-02
Lead concentrate	kg	1.36E+00
Lime	kg	1.41E-01
Natural gas	kg	1.04E-03
Nitrogen gaseous	kg	6.16E-02
Oxygen gaseous	kg	3.29E-01
Pyrite	kg	7.31E-02
Sand	kg	6.13E-02
Secondary material with medium content of Pb (>10% <80%)	kg	3.49E-02
Secondary material with high content of Pb (>80%)	kg	1.08E-03
Secondary material with low content of Pb (<10%)	kg	2.75E-01
Soda (sodium carbonate)	kg	5.83E-04
Steam	kg	4.70E-02
Waste (unspecified)	kg	5.32E-02
Outputs	**Unit**	**Quantity**

Lead bullion	kg	8.79E-01
Hazardous waste for land-filling	kg	1.17E-05
Internal lead material (internal recovery)	kg	2.78E-01
Non-hazardous waste for land-filling	kg	3.18E-01
Other metal concentrates	kg	5.02E-02
Secondary material with medium content of Pb (>10% <80%)	kg	2.09E-01
Secondary material with low content of Pb (<10%)	kg	4.63E-02
Slag	kg	5.76E-04
Waste (unspecified)	kg	3.39E-01

Table 3-5: Gate-to-gate data for the refining process per 1 kg refined lead from primary producers

Inputs	Unit	Quantity
Electricity	MJ	8.30E-01
Thermal energy from natural gas	MJ	2.30E+00
Alloying material (Sb, Mg, Al, Cu, Tn, Zn, Se)	kg	5.66E-03
Arsenic oxides	kg	1.16E-06
Calcium chloride	kg	4.04E-05
Hydrogen chloride	kg	1.74E-06
Lead bullion	kg	1.40E+00
Natural gas	kg	3.82E-03
Nitrogen gaseous	kg	1.67E-03
Oxygen gaseous	kg	3.78E-03
Pyrite	kg	2.50E-03
Secondary material with medium content of Pb (>10% <80%)	kg	2.24E-02
Sodium bicarbonate	kg	1.28E-04
Sodium hydroxide	kg	2.47E-03
Sodium nitrate	kg	8.29E-04
Sulphur	kg	2.66E-04
Steam	kg	8.76E-03
Outputs	**Unit**	**Quantity**
Refined lead (99%)	kg	1
Lead alloys (Pb, Sb, Mg, Al, Cu, Tn, Zn, Se)	kg	2.90E-01
Silver (dore, bullion, slime 20% Ag)	kg	8,12E-03
Dross and slimes	kg	1,20E-02
Filter dust (internal recovery)	kg	6.71E-04
Non-hazardous waste for land-filling	kg	1.77E-05
Other metal concentrates	kg	6.06E-04
Secondary material with medium content of Pb (>10% <80%)	kg	2.99E-02
Secondary material with high content of Pb (>80%)	kg	1.46E-03
Secondary material with low content of Pb (<10%)	kg	4.26E-03
Waste for incineration without energy recovery	kg	7.35E-06
Waste to recovery (unspecific)	kg	1.45E-02

Table 3-6: Gate-to-gate data for the site emissions to air from smelting and refining per 1 kg refined lead from primary producers

Outputs (emissions to air)	Unit	Quantity
Antimony	kg	1.13E-07
Arsenic	kg	2.39E-07
Cadmium	kg	7.68E-08
Copper	kg	5.69E-07
Lead	kg	6.48E-06
Mercury	kg	6.32E-08
Selenium	kg	9.28E-08
Tellurium	kg	2.75E-08
Tin	kg	1.45E-09
Zinc	kg	2.81E-06
Ammonium	kg	1.04E-07
Carbon dioxide	kg	6.61E-01
Carbon monoxide	kg	2.76E-04
Nitrogen dioxide	kg	1.29E-06
Nitrogen oxides	kg	3.96E-04
Nitrous oxide (laughing gas)	kg	9.13E-08
Sulphur dioxide	kg	5.52E-03
NMVOC (unspecified)	kg	3.40E-05
Methane	kg	2.43E-07
Dust (> PM10)	kg	7.17E-05

Table 3-7: Gate-to-gate data for the waste water treatment process per 1 kg refined lead from primary production mix

Inputs	Unit	Quantity
Electricity	MJ	1.30E-02
Waste water to be treated	kg	1.09E+01
Calcium hydroxide	kg	9.52E-04
Carbon dioxide	kg	1.07E-05
Flocculant	kg	9.79E-04
Hydrochloric acid (100%)	kg	1.08E-05
Lime	kg	6.57E-03
Oxygen gaseous	kg	3.75E-06
Sodium hydroxide	kg	5.64E-02
Sodium hypochlorite	kg	1.08E-05
Sulphuric acid	kg	3.95E-05
Water (tap water)	kg	3.74E-04
Steam	kg	1.74E-03
Ferrous sulphate	kg	2.91E-03
Outputs (including emissions to water)	**Unit**	**Quantity**
Antimony to water	kg	6.98E-07
Arsenic to water	kg	3.03E-07
Biological oxygen demand (BOD)	kg	2.21E-08

Cadmium to water	kg	1.67E-07
Chemical oxygen demand (COD)	kg	1.22E-07
Chromium to water	kg	8.64E-10
Cooling water	kg	2.98E-01
Copper to water	kg	3.06E-07
Iron to water	kg	6.67E-09
Lead to water	kg	2.50E-06
Mercury to water	kg	3.30E-09
Nickel to water	kg	1.54E-07
Nitrogen oxides	kg	2.63E-09
Processed water to river	kg	2.66E-08
Secondary material with low content of Pb (<10%)	kg	1.05E+01
Silver to water	kg	4.08E-03
Sulphate to water	kg	1.25E-10
Tin to water	kg	1.05E-03
Zinc to water	kg	4.60E-09

Table 3-8: Gate-to-gate data for the water use per 1 kg refined lead from primary producers

Inputs	Unit	Quantity
Ground water	kg	1.73E+01
Lake water	kg	3.78E+00
Rain water	kg	2.95E+00
River water	kg	6.47E+01
Water (tap water)	kg	5.69E-01
Outputs	**Unit**	**Quantity**
Cooling water	kg	3.10E+01
Cooling water to river	kg	5.51E+01
Processed water to groundwater	kg	5.98E-01
Water (waste water. untreated)	kg	6.77E-02
Water vapour to air	kg	1.47E+00

3.3.4. Transport

Transport, as defined in the scope of this report, was considered to be material for the major raw materials. In the case of the primary route, the transport of lead concentrate to the smelting facilities was modelled. Where companies did not provide company-specific data, an assumption of an average transport distance via truck within Europe and North America was made an assumed to be 500 km.

3.4. Background Data

All datasets used to develop the LCA models used in this study were sourced from the GaBi 2017 databases. Documentation for all these datasets is available online (thinkstep, 2018).

3.4.1. Fuels and Energy

Table 3-9 shows the most relevant LCI datasets used in modelling the product systems. Electricity consumption was modelled using national/regional grid mixes that account for imports from neighbouring countries/regions. Where country-specific datasets were not available, regional averages were used. Furthermore, where no regional average dataset was available German datasets were used.

Table 3-9: Key electricity and energy datasets used in inventory analysis

Energy	Location	Dataset	Data Provider	Reference Year	Proxy?
Electricity	DE, BE, GB, PT, AT, FR, IT, SE, CZ, BG, AU	Electricity grid mix	ts	2013	No
Technical heat	DE, BE, GB, PT, AT, FR, IT, SE, CZ, BG, CA	Thermal energy from natural gas	ts	2013	No
Fuel	DE	Coke mix	ts	2013	Yes

3.4.2. Upstream and Downstream Auxiliary Materials and Processes

Table 3-10 shows the most relevant LCI datasets used in modelling the product systems.

Table 3-10: Key material and process datasets used in inventory analysis

Material/ process	Location	Dataset	Data Provider	Reference Year	Proxy?
Limestone	DE, EU-28	Limestone (CaCO3; washed)	ts	2016	Yes
Sodium bicarbonate (Soda)	EU-28, US, DE	Soda (Na2CO3)	ts	2016	No
Antimony	CN	Antimony (Blast furnace route)	ts	2016	No
Tin	GLO	Tin	ts	2016	No
Magnesium	CN	Magnesium	ts	2016	No
Copper	GLO	Copper mix (99,999% from electrolysis)	ts	2016	No
Silver	GLO	Silver mix	ts	2016	No
Aluminium	DE, EU-28	Aluminium ingot mix	ts	2016	No
Inert waste to landfill	EU-28	Inert matter (Construction waste) on landfill	ts	2016	Yes
Hazardous waste for landfill	DE	Hazardous waste (no C, incl. landfilling)	ts	2016	Yes
Hazardous waste for incineration	DE, EU-28	Hazardous waste (statistic average) (no C, worst case scenario incl. landfil)	ts	2016	No

3.4.3. Transportation

Average transportation distances and modes of transport are included for the transport of the raw materials, operating materials, and auxiliary materials to production sites as defined in the scope of this study.

Transportation was modelled using the GaBi global transportation datasets. Fuels were modelled using the geographically appropriate datasets.

Table 3-11: Transport process datasets used in inventory analysis

Mode / fuels	Geographic Reference	Dataset	Data Provider	Reference Year	Proxy?
Truck, diesel driven	GLO	Truck, Euro 4, 28 - 32t gross weight / 22t payload capacity	ts	2016	no
Container ship, heavy fuel oil driven	GLO	Container ship, 27500 dwt payload capacity, ocean going	ts	2016	no
Rail, electricity and diesel driven	GLO	Rail transport cargo - average, average train, gross tonne weight 1000t / 726t payload capacity	ts	2016	no
Diesel	EU-28	Diesel mix at filling station	ts	2013	no
Electricity	EU-28	Electricity grid mix	ts	2013	no
Heavy Fuel Oil	EU-28	At refinery	ts	2013	no

3.5. Life Cycle Inventory Analysis Results

ISO 14044 defines the Life Cycle Inventory (LCI) analysis result as the “outcome of a Life Cycle Inventory analysis that catalogues the flows crossing the system boundary and provides the starting point for Llife Cycle Impact Assessment”. As the complete inventory comprises hundreds of flows, in Annex B only displays a selection of flows based on their relevance to the subsequent impact assessment in order to provide a transparent link between the inventory and impact assessment results.

4. Life Cycle Impact Assessment

This chapter contains the results for primary energy demand, global warming potential, acidification potential, eutrophication potential, and photochemical ozone creation potential, as well as additional metrics defined in section 2.6. For human toxicity, particulate matter, and land use change results, see Annex C: Additional Results. It shall be reiterated at this point that the reported impact categories represent impact potentials, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to 1 kg refined lead from primary route.

LCIA results are therefore relative expressions only and do not predict actual impacts, the exceeding of thresholds, safety margins, or risks.

4.1. Overall Results Summary

Table 4-1: Overall LCIA results for the primary production mix of 1 kg refined lead

Impact category	Mining and Beneficiation	Smelting	Refining	Waste Water Treatment	Smelting and Refining (Emissions to Air)	Total
PED [MJ]	4.48E+00	1.30E+01	5.36E+00	3.13E-01	-	2.31E+01
GWP [kg CO2 eq.]	2.54E-01	5.53E-01	3.31E-01	1.69E-02	6.61E-01	1.82E+00
AP [kg SO2 eq.]	1.65E-03	3.45E-03	2.89E-03	5.90E-05	6.82E-03	1.49E-02
EP [kg PO4-eq.]	2.49E-04	3.91E-04	2.98E-04	9.18E-06	5.18E-05	9.98E-04
POCP [kg Ethene eq.]	1.14E-04	1.39E-04	1.73E-04	3.65E-06	2.88E-04	7.18E-04

4.2. Primary Energy Demand

Primary energy demand is the quantity of energy directly taken from the environment prior to undergoing any anthropogenic changes and can be renewable (e.g. solar, hydropower) or non-renewable (e.g. coal, natural gas).

How primary energy demand is calculated varies according to the type of energy source. For fossil and nuclear fuels, primary energy demand is calculated as the energy content of the raw material. Similarly, the primary energy demand of renewable fuels is based on the energy content of the biomass used. For renewable energy technologies that directly generate electricity such as wind power, hydropower, solar power and geothermal power, the primary energy calculation is based on the efficiency of the conversion of the specific energy source (e.g. a wind turbine converts about 40% of the kinetic energy of the wind into electricity, so 1 MJ electricity requires around 2.5 MJ primary energy from wind).

Figure 4-1 shows the PED for the primary production mix of 1 kg refined lead. The smelting process contributes 56% to the PED.

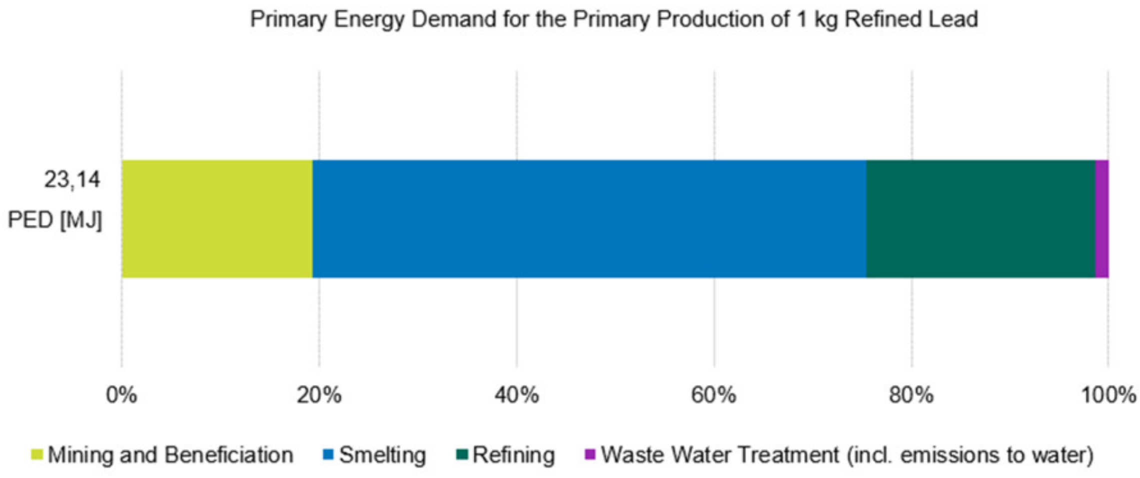


Figure 4-1: PED for the primary production mix of 1 kg refined lead

Figure 4-2 shows the main contributors to each process step for the PED for the primary production mix of 1 kg refined lead.

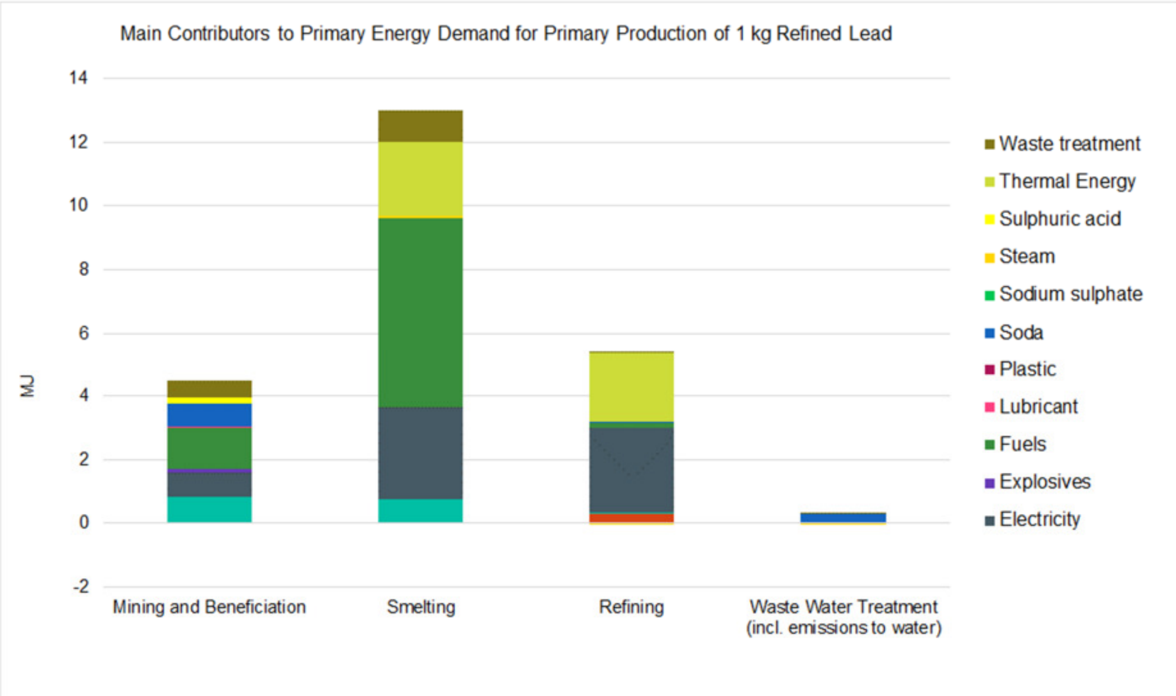


Figure 4-2: Main contributors to the PED for the primary production mix of 1 kg refined lead

The main contributors to the PED for the smelting process are the production of fuels and generation of electricity consumed. These fuels are mainly associated with the fuel source used for transport as well as those used in the furnaces. For the refining process, electricity is the major contributor to the PED. In total, the production of fuels contributes 32% to the total PED for the primary production mix of lead while electricity contributes 27%. Fuels associated with thermal energy make up 20% of the total PED.

4.3. Global Warming Potential

As the name suggests, the mechanism of the greenhouse effect can be observed on a small scale in a greenhouse; incoming solar energy is trapped, causing the internal temperature to rise. This effect also occurs on a global scale. When short-wave ultraviolet radiation from the sun meets the Earth's surface some energy is re-emitted as longer wave infrared radiation. Instead of directly heading back out to space, some of this infrared radiation is absorbed by greenhouse gases in the troposphere and re-radiated in all directions, including back to earth. This results in a warming effect at the earth's surface. In addition to the natural mechanism, the greenhouse effect is enhanced by human activities. Greenhouse gases that are considered to be caused, or increased, anthropogenically include, for example, carbon dioxide, methane and CFCs. Since the residence time of the gases in the atmosphere is incorporated into the calculation, a time range for the assessment must also be specified; a period of 100 years is customary. Figure 4-3 shows the global warming potential for the primary production mix of 1 kg refined lead.

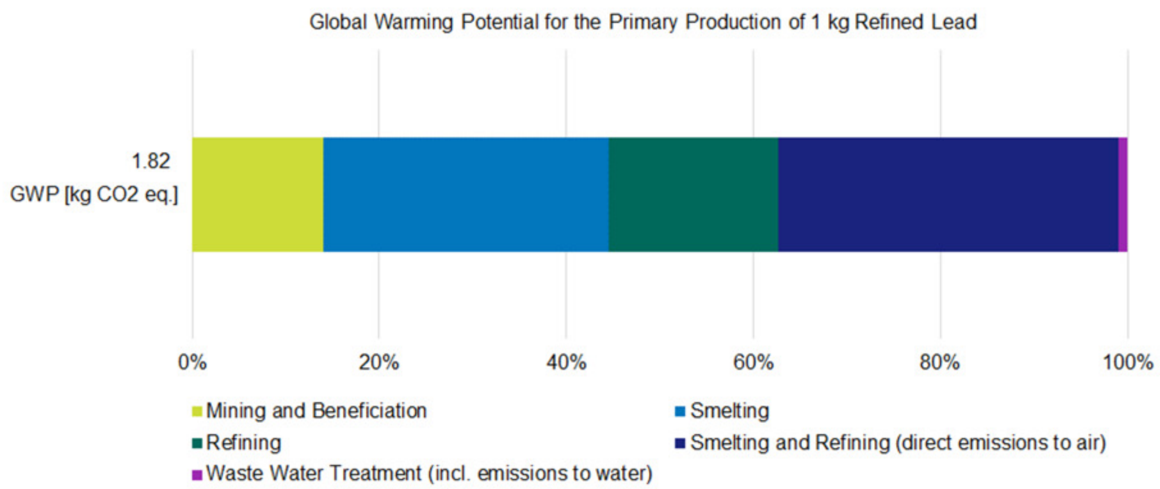


Figure 4-3: GWP for the primary production mix of 1 kg refined lead

Emissions associated with the smelting and refining processes contribute almost 36% to the total GWP for the primary production of lead. The smelting process contributes nearly 30% to the GWP and the refining process contributes approximately 18% to the GWP.

Figure 4-4 shows the main contributors to the global warming potential for the primary production mix of 1 kg refined lead.

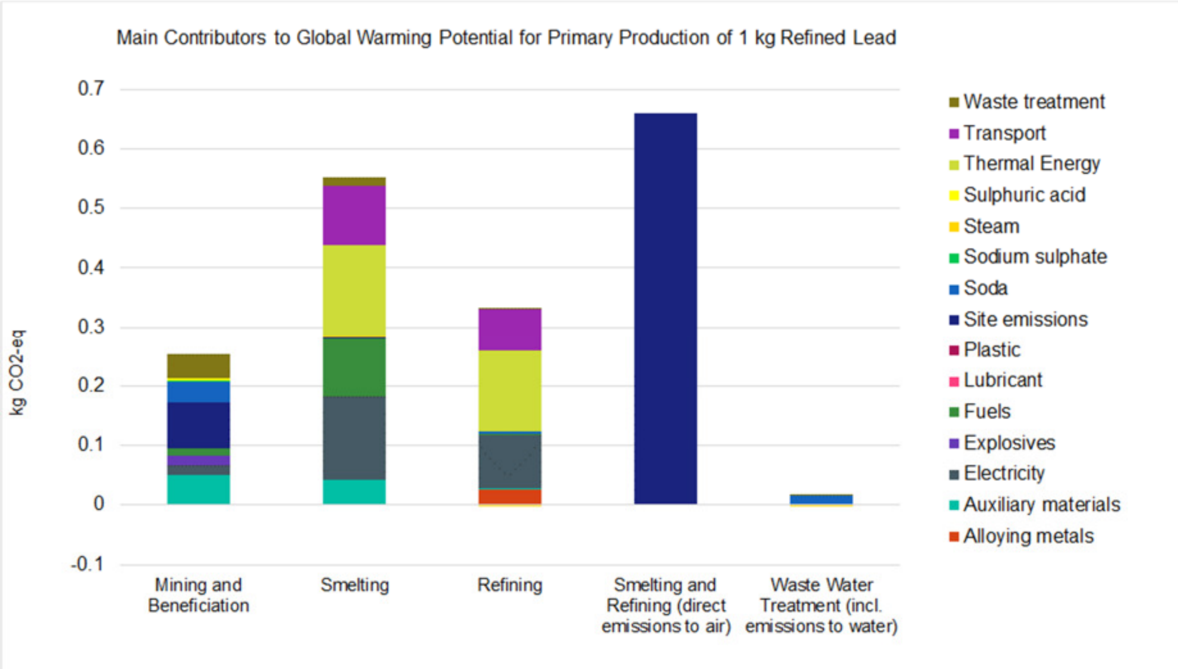


Figure 4-4: Main contributors to the GWP for the primary production mix of 1 kg refined lead

In Figure 4-4, carbon dioxide (CO_2) contributing to site emissions arises mainly from onsite combustion emissions associated with the smelting and refining processes. CO_2 arising from the various process steps mainly arises from the production and combustion of fossil fuels used for transport, thermal energy and for the generation of the electricity consumed in these processes. For the mining and beneficiation process, 30% of the GWP arises from the combustion of fuel associated with mining transport activity.

4.4. Acidification Potential

The acidification of soils and waters occurs predominantly through the transformation of air pollutants into acids. This leads to a decrease in the pH-value of rainwater and fog from 5.6 to 4 and below. Sulphur dioxide and nitrogen oxide and their respective acids (H_2SO_4 und HNO_3) produce relevant contributions. This damages ecosystems, whereby forest dieback is the most well-known impact.

Acidification has direct and indirect damaging effects (such as nutrients being washed out of soils or an increased solubility of metals into soils). But even buildings and building materials can be damaged. Examples include metals and calcium carbonate-based rocks (e.g. marble, limestone), which are corroded or disintegrated at an increased rate. Figure 4-5 shows the acidification potential of the primary production mix of 1 kg refined lead.

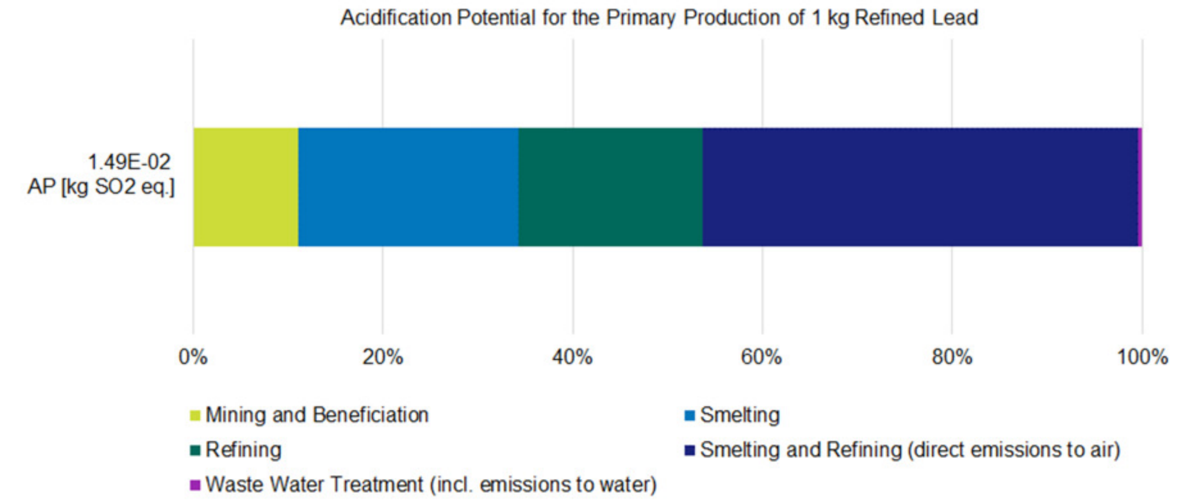


Figure 4-5: AP for the primary production mix of 1 kg refined lead

For the primary production mix of lead, the major contributor to the AP for 1 kg refined lead arises from sulphur dioxide (SO_2) released during the combustion of fossil fuels from the smelting and refining processes. These emissions contribute 46% to the total AP.

Figure 4-6 shows the main contributors to the AP for the primary production mix of 1 kg refined lead.

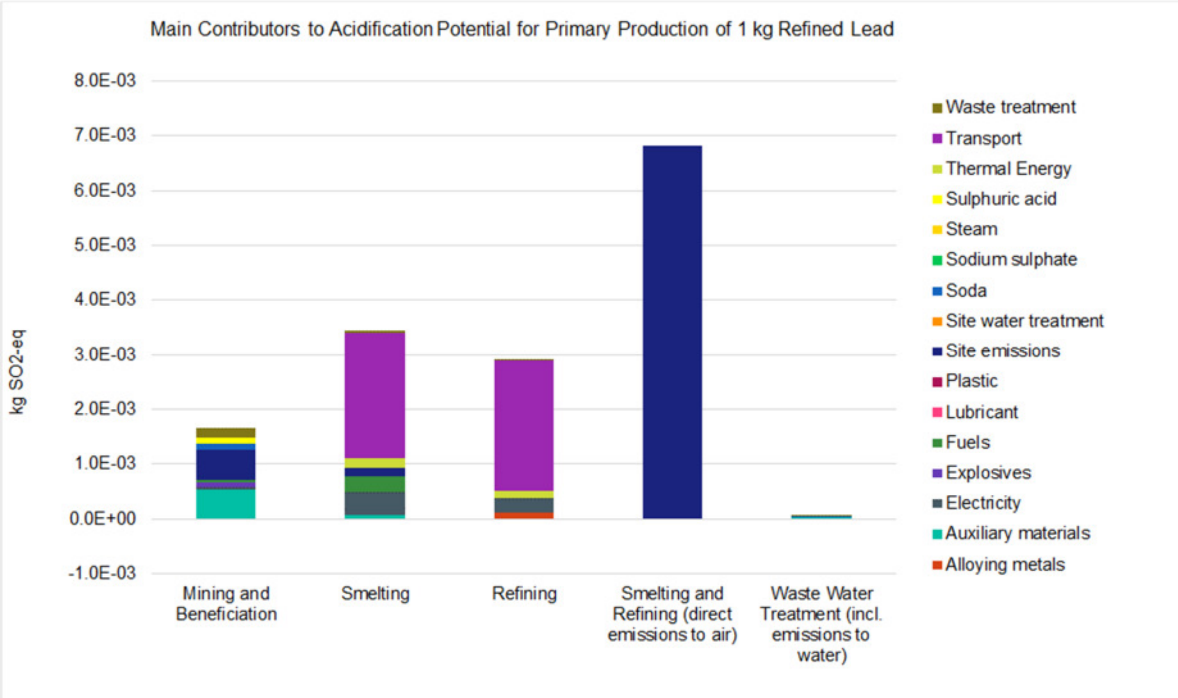


Figure 4-6: Main contributors to the AP for the primary production mix of 1 kg refined lead

Emissions associated with transport in the smelting and refining process contributes 31% to the total AP, while electricity in total only contributes 5% to the total AP. In the case of mining and beneficiation, direct emissions are mainly attributed to diesel consumption associated with transport activities on site.

4.5. Eutrophication Potential

Eutrophication is the enrichment of nutrients in a certain place. Eutrophication can be aquatic or terrestrial. Air pollutants, waste water and fertilization in agriculture all contribute to eutrophication.

The result in water is an accelerated algae growth, which in turn, prevents sunlight from reaching the lower depths. This leads to a decrease in photosynthesis and less oxygen production. In addition, oxygen is needed for the decomposition of dead algae. Both effects cause a decreased oxygen concentration in the water, which can eventually lead to fish dying and to anaerobic decomposition (decomposition without the presence of oxygen). Hydrogen sulphide and methane are thereby produced, further damaging the eco-system.

Overly nutrient enriched soils may result in an increased susceptibility of plants to diseases and pests as well as degradation of plant stability. If the nutrification level exceeds the amounts of nitrogen necessary for a maximum harvest, it can lead to an enrichment of nitrate. This can cause, by means of leaching, increased nitrate content in groundwater and may also end up in drinking water. Nitrate at low levels is harmless from a toxicological point of view. However, nitrite, a reaction product of nitrate, is toxic to humans.

Figure 4-7 shows the eutrophication potential (EP) for the primary production mix of 1 kg refined lead.

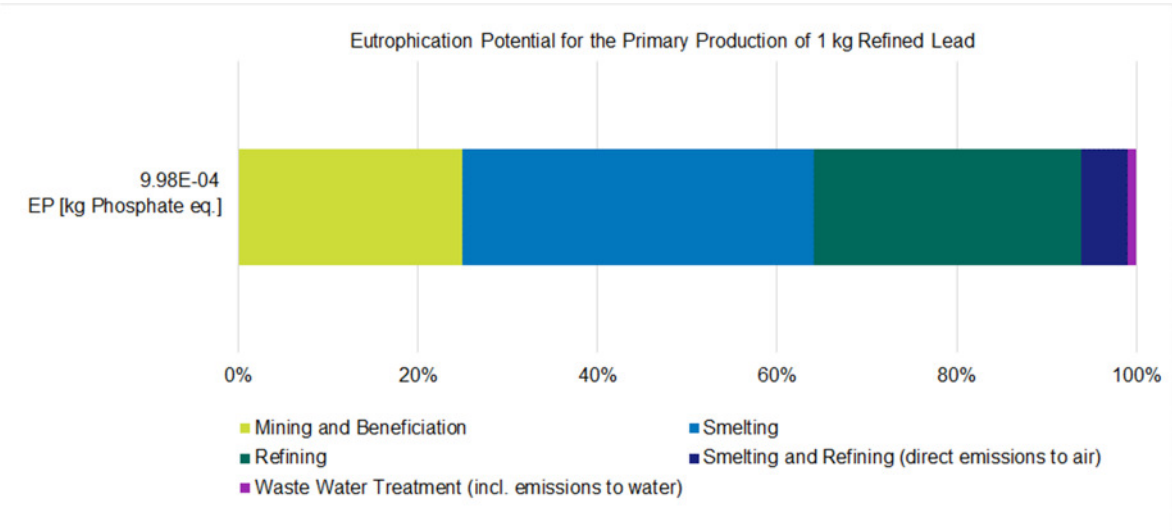


Figure 4-7: EP for the primary production mix of 1 kg refined lead

For the primary production mix of lead, the smelting process contributes 39% to the total EP, while the refining process makes up 30% of the total EP.

Figure 4-8 shows the main contributors to the EP for the primary production mix of 1 kg refined lead.

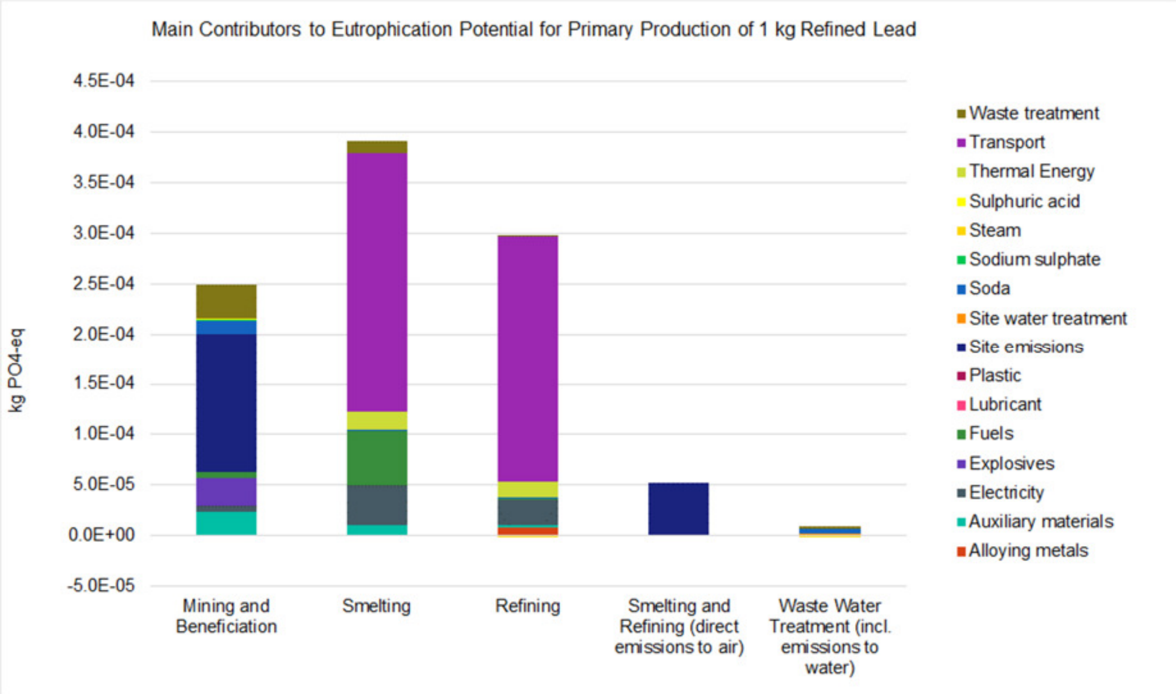


Figure 4-8: Main contributors to the EP for the primary production mix of 1 kg refined lead

Emissions associated with transport in the smelting and refining processes contribute 50% to the total EP for the primary production mix of lead. In the smelting process, the upstream generation of electricity consumed and production of fuels contribute 6% to the total EP. Emissions associated with the combustion of diesel for mining activities contribute 14% to the total EP while explosives contribute 3% to the total EP.

4.6. Photochemical Ozone Creation Potential

Despite playing a protective role in the stratosphere, at ground-level ozone is classified as a damaging trace gas. Photochemical ozone production in the troposphere, also known as summer smog, is suspected to damage vegetation and material. High concentrations of ozone are toxic to humans.

In the presence of nitrogen oxides and hydrocarbons (e.g. VOCs), ultraviolet radiation from the sun drives complex chemical reactions, producing aggressive reaction products, one of which is ozone. Nitrogen oxides alone do not cause high ozone concentration levels.

Hydrocarbon emissions occur from incomplete combustion, in conjunction with petrol (storage, turnover, refuelling etc.) or from solvents. High concentrations of ozone arise when the temperature is high, humidity is low, when air is relatively static and when there are high concentrations of hydrocarbons. Today it is thought that the presence of nitrogen monoxide (NO) and carbon monoxide (CO) reduces the accumulated ozone to NO_2, CO_2 and O_2. Surprisingly, this means, that high concentrations of ozone may not necessarily occur near hydrocarbon emission sources but can occur in less polluted areas.

Figure 4-9 shows the photochemical ozone creation potential (POCP) for the primary production mix of 1 kg refined lead.

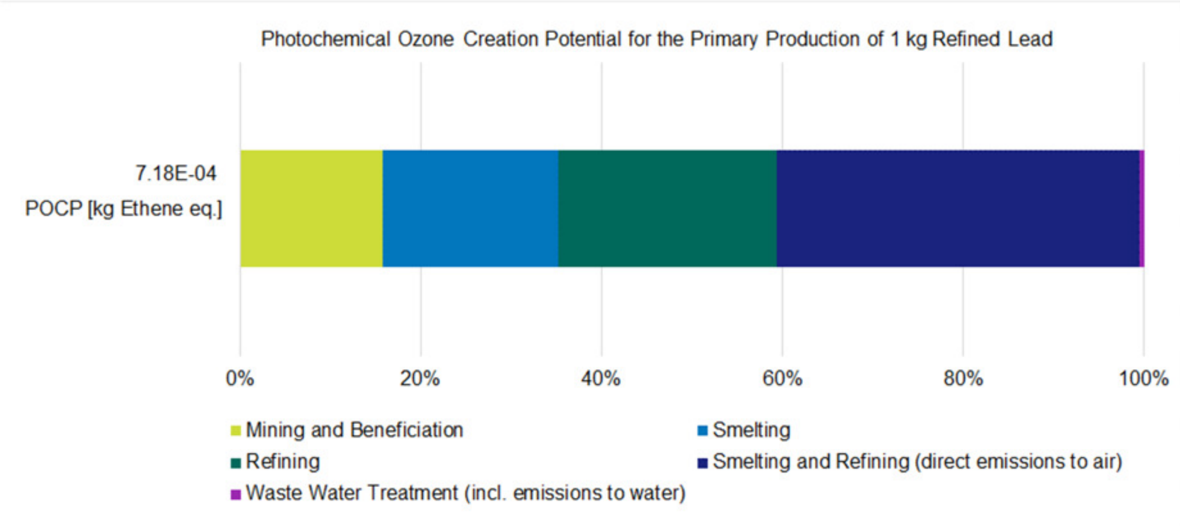


Figure 4-9: POCP for the primary production mix of 1 kg refined lead

Direct emissions (mainly SO_2 and NO_X) resulting from the smelting and refining processes contribute 40% to the total POCP for the primary production mix of refined lead, while the refining process makes up 24% of the overall POCP.

Figure 4-10 shows the main contributors to the POCP for the primary production mix of refined lead.

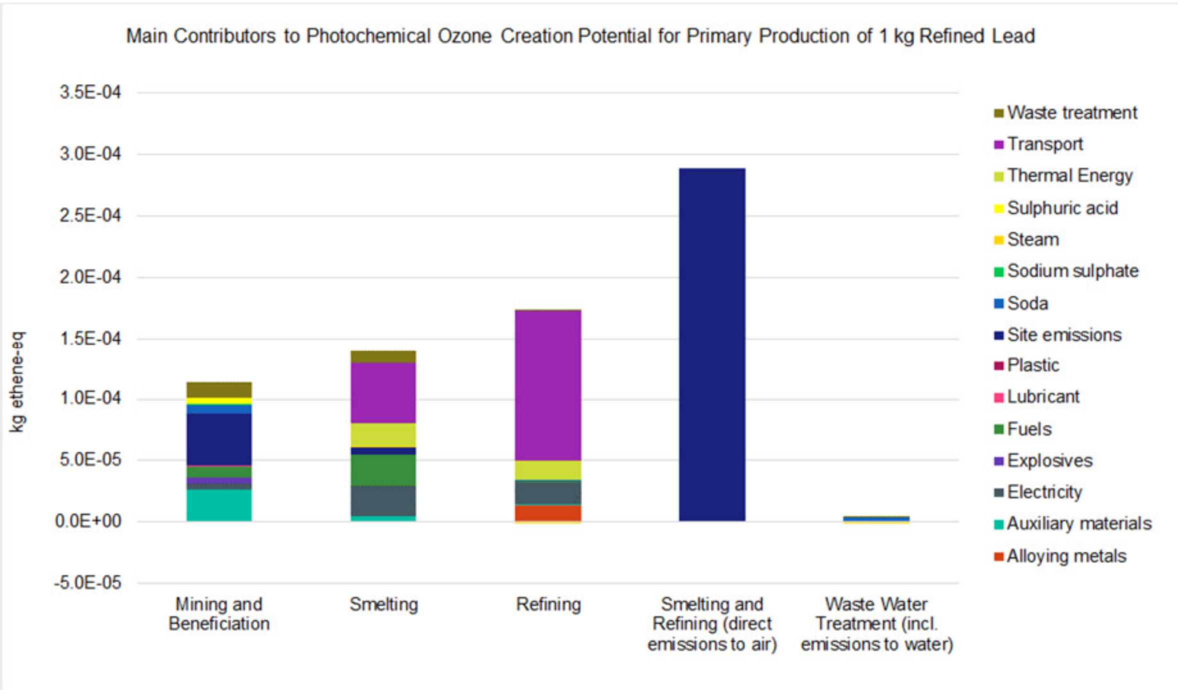


Figure 4-10: Main contributors to the POCP for the primary production mix of 1 kg refined lead

Emissions associated with the combustion of fossil fuels contribute to the direct emissions associated with the smelting and refining processes. Emissions resulting from transport in the refining process contributes 17% to the total POCP. In the mining and beneficiation process, auxiliary materials contribute 4% to the total POCP.

5. Interpretation

5.1. Identification of Relevant Findings

Table 5-1 presents a summary of the largest drivers of results. Further details can be found in the sub-sections below.

Table 5-1: Summary of results contributors in percentage

Impact category	Main category contributing to overall results	Main production process contributing to overall results	Main input/output contributing to overall results
PED	Smelting (56%) Refining (23%)	Electricity (23%) Fuels (40%) Thermal energy (20%)	Hard coal (29%) Natural gas (23%) Crude oil (22%)
GWP	Smelting + refining (direct emissions to air) (36%) Smelting (30%)	Site emissions (41%) Thermal energy (16%) Electricity (16%)	Carbon dioxide (91%)
AP	Smelting + refining (direct emissions to air) (46%) Smelting (23%)	Site emissions [51%] Transport [31%]	Sulphur dioxide (76%) Nitrogen oxides (22%)
EP	Smelting (39%) Refining (30%)	Transport (50%) Site emissions (19%)	Nitrogen oxides (86%)
POCP	Smelting + refining (direct emissions to air) (40%) Smelting (24%)	Site emissions (47%) Transport (24%)	Sulphur dioxide (63%) Nitrogen oxides (26%)

Primary Energy Demand

The primary energy demand (PED) is the quantity of energy directly taken from the environment prior to undergoing any anthropogenic changes. For the primary production mix of lead, the smelting process has the largest contribution to the PED with 59% resulting from the consumption of hard coal and natural gas. Mining and beneficiation makes up 19% of the total PED, with crude oil having the largest contribution (37%) to this process.

Coke and natural gas are the fuels added to the blast furnace along with oxygen, the flux (limestone) and ore to facilitate the chemical reaction required to extract the metal. The smelting process in the primary route consumes 0.11 kg coke per 1 kg refined lead is required. Coke is produced from hard coal and has a net calorific value of 35.2 MJ / kg coke. Therefore, approximately 3.9 MJ of coke / kg refined lead is required for the primary route along with 0.87 MJ of thermal energy from natural gas.

The consumption as described above reflects only the fuel required for the furnace; the balance is attributed to the resources required for production of electricity grid and upstream ancillary materials. Similarly, renewable energy resources contributing to the PED are mainly associated with the electricity grid mix. Crude oil contributing to the PED for the mining and beneficiation process is largely attributed to diesel consumption for mining activities and in some cases diesel generators. Crude oil contributing to the PED for the smelting process in the primary route is largely associated with transport of raw material to site which includes diesel for trucks and heavy fuel oil for ships.

Global Warming Potential

Greenhouse gases (GHG) including CO_2, methane (CH_4) and N_2O are associated with the combustion of fossil fuels and therefore the GWP is typically closely linked to the PED profile. Fossil fuels including hard coal, natural gas and crude oil are primarily composed of carbon-compounds (i.e. carbon, methane or hydrocarbons) and small quantities of sulphur, nitrogen and oxygen. For the primary production mix of lead CO_2 is the major contributor (more than 90%) to the GWP since fossil fuels make up approximately 80% of the PED. Approximately 36% of the GWP arises from CO_2 emissions related to onsite fuel combustion. Site emissions primarily consist of the combustion emissions of coke and other fuels excluding natural gas, since the thermal energy from natural gas was modelled with a GaBi 2017 dataset. These combustion emissions are therefore reflected under the smelting process.

Acidification Potential

Sulphur (S) and nitrogen (N) containing compounds are the main contributors to the acidification potential as these compounds when reacting with water (water vapour) create acids that enter the atmosphere, water and soil creating acidification. These sulphur and nitrogen compounds primarily originate from the combustion of fossil fuels. Similar to the GWP profile for the primary route, SO_2 from the onsite combustion of fuels are the main contributor to the AP of 1 kg refined lead. Sulphur dioxide (SO_2) contributes 76% to the total AP. Nitrogen oxides (NO_x) are with 22% the second largest contributor to the AP of the various processes for the primary production mix of lead.

Eutrophication Potential

Along with the release of nitrogen containing compounds, emissions associated with acidification are also closely linked with increased nutrient concentrations that result in eutrophication. For the primary production mix of lead, the smelting process has the highest contribution (44%) to the EP. NO_x emissions contribute 86% to the total eutrophication potential (EP) for the primary production mix of refined lead. These NO_x emissions mainly result from transport activities, the production of alloying metals, the generation of electricity consumed and thermal energy from natural gas. Unlike the trend for other impact categories under study, the mining and beneficiation process has a significant contribution to the EP as a result of the use of explosives and mining transport activities.

Photochemical Ozone Creation Potential

Photochemical smog is produced when ultraviolet radiation from the sun drives complex reactions between nitrogen oxides and hydrocarbons in the atmosphere, resulting in airborne particles and ground-level ozone – smog. Nitrogen oxides are released during the combustion of fossil fuels while hydrocarbon emissions occur from incomplete combustion of fossil fuels, in conjunction with gasoline (storage, turnover, refuelling etc.) or from solvents. For the primary production mix of lead, sulphur dioxide is the largest contributor to the POCP resulting from the onsite combustion of fuels. Sulphur dioxide is also a pollutant that forms part of smog. SO_2 contributes 63% to the total POCP for the primary production mix of lead and mainly arises from the onsite combustion of fossil fuels associated with smelting and refining processes. NO_x emissions are also large contributors to the mining and beneficiation, smelting and refining processes, making up 39%, 49% and 35% of the POCP of these processes respectively.

5.2. Assumptions and Limitations

As with many industrial facilities, it can be difficult to provide the precise data requested by the study practitioners, and therefore to ensure data is provided and used at the level as required in this study certain assumptions are made.

In some cases, only a single figure for electricity or energy was available for a total site, and in these cases the data providers relied on internal experts to provide the appropriate split to products and processes based on expert judgement. As the total energy required gate-to-gate is not affected by this assumption, there would be no change to results, however it would affect the relative results of each process.

Where companies did not report emissions to air and water as requested in the questionnaire, an average per kilogram of lead was derived from a minimum of three companies who have reported and scaled based on production volume. The exception is carbon dioxide, which if not provided was calculated based on carbon-containing inputs and fuels. Additionally, if companies explicitly stated that fuel combustion emissions were not included in the emissions to air reported, GaBi data were used to model fuel combustion emissions.

All sites have exchanges of lead-containing secondary materials between processes, including refining, smelting, and waste water treatment. Also, a significant amount of lead-containing material could be stored on site for future use. As these quantities are all difficult to track in an industrial facility, assumptions were made about these internally looped lead-containing materials to ensure the mass and metal contents balanced between the inputs and outputs.

If no specific information regarding waste treatment was provided by participating companies (e.g. landfill, incineration, recovery/sold) and due to the lack of specific background data for lead waste treatments, these unspecified waste flows were treated as hazardous waste to incineration and vitrification without carbon content. Hazardous waste (unspecified) were treated with a general assumption provided by ILA; 10% hazardous waste incineration and vitrification (without providing a credit for a possible lead recovery), remaining 90% sent to landfill for inert waste. The alloying elements (on average, 1% of the total mass into the refinery) have a significant contribution to the impact of the refining process.

The primary route is modelled considering a concentrate mix from Canada, Australis, Portugal and Sweden. While the smelting and refining is in Canada, and other countries in Europe as can be seen in Table 3-1..

5.3. Sensitivity Analysis

Sensitivity analysis tries to determine the influence of variations in assumptions, methods and data on the results. According to ISO 14044 Standard, whenever several alternative allocation procedures seem applicable, a sensitivity analysis shall be conducted to illustrate the consequences of the departure from the selected approach.

The procedure of sensitivity analysis is a comparison of the results obtained using certain given assumptions, methods or data with the results obtained using alternative assumptions, methods or data. In this study, mass allocation was selected as the preferred allocation method in the refining step of the primary lead production.

An economic allocation to the valuable metal content of reported output streams was applied using the prices as presented in Table 5-2 below.

Table 5-2: Sensitivity analysis – economic allocation prices

Refining output material	Average price (€ / kg)
Refined lead >99%	1.84[2]
Lead alloys 95% Pb	1.74[2]
Silver (dore, bullion, slime 20% Ag)	479.81[3]
Secondary Pb (10%)	0.18[2]

Table 5-3: Sensitivity analysis for by-products from the refining step

Sensitivity analysis results in percentage (%) of contribution to overall results	
GWP [kg CO2 eq.]	-10%
PED [MJ]	-18%
AP [kg SO2 eq.]	-5%
EP [kg Phosphate eq.]	-9%
POCP [kg Ethene eq.]	-7%

The results of the sensitivity show less than 10% reduction in all impact categories except for PED. The economic allocation show that the environmental profile would improve however, data provided for the various metal intermediate products at the refining step was not consistently reported by all participating companies.

Although the effort of companies providing all data as requested, the amount of refined lead and lead alloys produced was consistently provided but minor other materials were not reported by all. Since a full record of other metal or metal containing materials outputs was not possible, the average gate-to gate data does not fully represent all possible co-products from primary lead production, due to this constraint a mass allocation was preferred as a conservative approach.

5.4. Data Quality Assessment

Inventory data quality is judged by its precision (measured, calculated or estimated), completeness (e.g., unreported emissions), consistency (degree of uniformity of the methodology applied) and representativeness (geographical, temporal, and technological).

To cover these requirements and to ensure reliable results, first-hand industry data in combination with consistent background LCA information from the GaBi 2017 database were used. The LCI datasets from the GaBi 2017 database are widely distributed and used with the GaBi 8 Software. The

[2] London Metal Exchange, world centre for the trading of industrial metals: https://www.lme.com/en-GB/Metals/Non-ferrous#tabIndex=0

[3] Financial portal: https://www.onvista.de/rohstoffe/Silberpreis-26263301

datasets have been used in LCA models worldwide in industrial and scientific applications in internal as well as in many critically reviewed and published studies. In the process of providing these datasets they are cross-checked with other databases and values from industry and science.

5.4.1. Precision and Completeness

- ✓ **Precision:** As the majority of the relevant foreground data are measured data or calculated based on primary information sources of the owner of the technology, precision is considered to be very good. Seasonal variations/variations across different manufacturers were balanced out by using yearly averages/weighted averages. All background data are sourced from GaBi databases with the documented precision.
- ✓ **Completeness:** Each foreground process was checked for mass balance and completeness of the emission inventory. No data were knowingly omitted. Completeness of foreground unit process data is considered to be good. Emissions which are not regularly measured or calculated e.g. fugitive emissions have not been included. All background data are sourced from GaBi databases with the documented completeness.

5.4.2. Consistency and Reproducibility

- ✓ Consistency: To ensure data consistency, all primary data were collected with the same level of detail, while all background data were sourced from the GaBi databases.
- ✓ Reproducibility: Reproducibility is supported as much as possible through the disclosure of input-output data, dataset choices, and modelling approaches in this report. Based on this information, any third party should be able to approximate the results of this study using the same data and modelling approaches.

5.4.3. Representativeness

- ✓ **Tempora**l: All primary data were collected for the year 2015 All secondary data come from the GaBi 2017 databases and are representative of the years 2013-2016. As the study intended to analyse the product systems for the reference year 2015, temporal representativeness is considered to be high.
- ✓ **Geographical**: All primary and secondary data were collected specific to the countries or regions under study. Where country-specific or region-specific data were unavailable, proxy data were used, e.g. if no country specific was available a technological representative dataset has been used with preference from the same region or global. Geographical representativeness is considered to be very good.
- ✓ **Technological**: All primary and secondary data were modelled to be specific to the technologies or technology mixes under study. Where technology-specific data were unavailable, proxy data were used. Please see Table 3-9 to Table 3-11 for more details. Technological representativeness is considered to be very good.

5.5. Model Completeness and Consistency

5.5.1. Completeness

All relevant process steps for each product system were considered and modelled to represent each specific situation. The process chain is considered sufficiently complete and detailed with regards to the goal and scope of this study.

5.5.2. Consistency

All assumptions, methods and data are consistent with each other and with the study's goal and scope. Differences in background data quality were minimised by exclusively/predominantly using LCI data from the GaBi 2017 databases. System boundaries, allocation rules, and impact assessment methods have been applied consistently throughout the study.

5.6. Conclusions, Limitations, and Recommendations

This study presents a comprehensive LCA of the European and North American industry-average mix for primary lead production for all applications. The conclusions drawn here can be extrapolated across the entire industry. The study covers the main lead smelting technologies (rotary, blast, shaft, TSL, QSL, Reverb), with the contributing industry data representing 86% of primary production for those technologies in Europe and North America during the study period.

The LCA provides a comprehensive evaluation of the impacts associated with primary lead production mix from a cradle-to-gate perspective.

It is clear from this study's analysis that the bullion smelting, and successive refining are the dominant contributors to environmental impacts associated with the primary production of lead metal, contributing between 43% and 79% to the impact categories presented in this report. While the mining and beneficiation contributes between 11% to 25%, being the Eutrophication potential the highest due to the production and combustion of diesel used by the trucks during the mining process.

To demonstrate conformity with relevant ISO standards (ISO 14040 and ISO 1444) a critical review by an external expert has been carried out (see Annex A: External Critical Review Report), as specified in the Goal and Scope sections of this report (sections 1 and 2.11).

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Annex A: Critical Review Statement

Critical Review Statement

LIFE CYCLE ASSESSMENT OF PRIMARY LEAD PRODUCTION MIX - EUROPE AND NORTH AMERICA

Commissioned by:	International Lead Association (ILA), United Kingdom
Prepared by:	thinkstep AG, Germany
Reviewer:	Prof. Dr. Matthias Finkbeiner, Germany
References	ISO 14040 (2006): Environmental Management - Life Cycle Assessment - Principles and Framework ISO 14044 (2006): Environmental Management - Life Cycle Assessment – Requirements and Guidelines ISO/TS 14071 (2014): Environmental management -Life cycle assessment - Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006

Scope of the Critical Review

The reviewer had the task to assess whether

- the methods used to carry out the LCA are consistent with the international standards ISO 14040 and ISO 14044,
- the methods used to carry out the LCA are scientifically and technically valid,
- the data used are appropriate and reasonable in relation to the goal of the study,
- the technological coverage of the industry in the prevalent LCA study is representative of current practice,
- the interpretations reflect the limitations identified and the goal of the study, and
- the study report is transparent and consistent.

The review was performed concurrently to the study according to paragraph 6.2 of ISO 14044, because the study is not intended to be used for comparative assertions intended to be disclosed to the public. This review statement is only valid for this specific report in its final version 4.0 dated 21.08.2018.
The analysis of the LCI model and the verification of individual datasets are outside the scope of this review.

Review process

The review process was coordinated between ILA, thinkstep and the reviewer. As a first step in the review process, a kick-off call was held on 09.12.2016. In this call, the details of the review process were agreed, and an outline of the goal and scope of the study was presented by thinkstep. The first draft of the goal and scope report was submitted to the reviewer on 10.12.2016. The reviewer provided 41 comments of general, technical and editorial nature to the commissioner by 20.12.2016. A revised goal and scope definition and responses to the reviewer comments were delivered on 06.04.2018. The reviewer acknowledged the actions taken on the comments and did not have additional technical comments at this stage of the process. It should be noted, that the original goal and scope report from 2017 was a common document for this study and parallel studies of ILA on the secondary lead production mixes in Europe and North America. Later in the process, it was decided to present results in separate reports. As such, the comments addressed here are specific to this study, but partly identical to the comments provided for the separately available reports on secondary production.

As a next step, the commissioner provided the first draft of the final report on 19.06.2018. The reviewer provided 56 comments on the draft final report of general, technical and editorial nature and sent them to the commissioner by 28.06.2018.

ILA and thinkstep provided a comprehensively revised report and documentation on the implementation of the review comments on 20.07.2018. All critical issues and the majority of recommendations of the reviewer were addressed in a proper manner. Just four open issues remained, which were resolved in a critical review meeting with thinkstep (web-meeting) held on 16.08.2018.

The final version 4.0 of the report was provided on 21.08.2018.

The reviewer checked the implementation of the comments and agreed to conclude the critical review process. The reviewer acknowledges the unrestricted access to all requested information as well as the open and constructive dialogue during the critical review process.

General evaluation

The goal of the study was to assess the life cycle environmental profile of the primary lead production mix in Europe and North America. The study was performed in a professional manner using state-of-the-art methods. An outstanding feature of the study was the high representativeness with regard to industrial primary data as the primary lead producing companies involved in this study represent 86% of the production volume. Primary data were collected by 10 companies with sites in Bulgaria, United Kingdom, Germany, Alaska, Canada, Portugal, Sweden and Australia.

The LCI data are provided as cradle-to-gate without use phase and end-of-life recycling. Because the focus of the study is the production of a material that can be used in a variety of products with very different use profiles, the chosen cradle-to-gate-approach is appropriate. As the decisions involved in modeling co-product and end-of-life allocation contain value

choices it is appreciated, that ILA and thinkstep provide a transparent documentation of the approaches chosen including some sensitivity analyses.
As a result, the scope defined for this study was found to be appropriate to achieve the stated goals.

Conclusion

The study has been carried out in conformity with ISO 14040 and ISO 14044 following the critical review procedures of ISO 14071. The reviewer found the methodology and its execution to be adequate for the defined purposes of the study. The study is reported in a comprehensive manner including a transparent documentation of its scope and methodological choices.

27th August 2018

Matthias
Finkbeiner

Annex B: LCI Results

Table 5-4: LCI results for the cradle-to-gate primary production mix of 1 kg refined lead

Type	Flow	Mining and Beneficiation	Smelting	Refining	Smelting and Refining (direct emissions to air)	Waste Water Treatment (incl. emissions to water)	Total
Inputs							
Energy resources [MJ]	Coalbed methane	9.77E-05	1.24E-03	3.93E-04	0.00E+00	1.13E-06	1.73E-03
	Crude oil	3.96E-02	4.98E-02	2.81E-02	0.00E+00	9.26E-04	1.18E-01
	Hard coal	1.53E-02	2.16E-01	2.37E-02	0.00E+00	1.72E-03	2.56E-01
	Lignite	1.85E-02	6.00E-02	2.27E-02	0.00E+00	3.28E-03	1.05E-01
	Natural gas	2.12E-02	4.59E-02	4.99E-02	0.00E+00	1.74E-03	1.19E-01
	Oil sand (10% bitumen)	3.43E-03	8.66E-03	1.49E-04	0.00E+00	1.49E-05	1.23E-02
	Oil sand (100% bitumen)	3.00E-04	7.56E-04	1.30E-05	0.00E+00	1.30E-06	1.07E-03
	Peat	2.63E-04	6.69E-05	5.11E-05	0.00E+00	2.08E-05	4.02E-04
	Pit Methane	1.14E-04	5.76E-04	1.84E-04	0.00E+00	1.48E-05	8.89E-04
	Shale gas	1.22E-04	1.71E-03	4.60E-04	0.00E+00	4.28E-06	2.30E-03
	Tight gas	1.46E-04	7.27E-03	2.10E-03	0.00E+00	3.94E-06	9.52E-03
	Uranium natural	9.85E-07	1.29E-06	6.56E-07	0.00E+00	9.43E-08	3.02E-06
Material resources [kg]	Air	9.27E-01	1.38E+02	2.57E+00	0.00E+00	1.99E-01	1.42E+02
	Anhydrite (Rock)	3.74E-15	1.27E-16	2.19E-16	0.00E+00	4.38E-16	4.52E-15
	Antimony	3.00E-09	1.52E-09	1.60E-05	0.00E+00	2.25E-11	1.60E-05
	Barium sulphate	7.35E-15	1.62E-15	1.14E-15	0.00E+00	7.80E-16	1.09E-14
	Basalt	5.46E-08	9.60E-08	4.69E-08	0.00E+00	5.77E-09	2.03E-07
	Bauxite	1.11E-02	9.40E-05	8.97E-05	0.00E+00	3.73E-04	1.17E-02
	Bentonite	1.46E-04	2.98E-04	9.88E-05	0.00E+00	3.55E-06	5.46E-04
	Borax	9.15E-09	2.64E-10	1.40E-10	0.00E+00	6.81E-12	9.56E-09
	Calcium chloride	7.53E-13	1.66E-13	1.16E-13	0.00E+00	7.98E-14	1.11E-12
	Carbon dioxide	1.99E-02	4.17E-02	2.00E-02	0.00E+00	1.86E-03	8.35E-02
	Chromium	1.29E-06	1.41E-06	1.05E-06	0.00E+00	8.44E-08	3.83E-06
	Clay	1.95E-03	1.36E-02	4.39E-04	0.00E+00	3.53E-05	1.60E-02
	Cobalt	1.97E-11	3.92E-11	1.89E-11	0.00E+00	1.93E-12	7.97E-11
	Colemanite ore	1.03E-03	9.01E-07	3.98E-07	0.00E+00	1.67E-06	1.03E-03
	Copper	1.73E-04	1.88E-05	9.20E-05	0.00E+00	1.10E-06	2.85E-04
	Dolomite	3.86E-05	9.63E-05	4.84E-03	0.00E+00	3.90E-06	4.98E-03
	Feldspar (aluminium silicates)	1.63E-21	3.70E-21	1.20E-21	0.00E+00	3.06E-22	6.83E-21
	Ferro manganese	2.47E-17	5.60E-17	1.82E-17	0.00E+00	4.63E-18	1.03E-16
	Fluorspar (calcium fluoride; fluorite)	3.04E-06	3.07E-06	1.74E-06	0.00E+00	1.83E-07	8.04E-06
	Gold	1.40E-10	2.34E-10	5.94E-10	0.00E+00	1.39E-11	9.82E-10
	Granite	1.63E-21	3.70E-21	1.20E-21	0.00E+00	3.06E-22	6.84E-21
	Graphite	8.61E-06	1.76E-10	8.40E-11	0.00E+00	8.30E-12	8.61E-06
	Ground water	9.42E+00	8.85E-01	2.99E-01	0.00E+00	8.44E+00	1.91E+01
	Gypsum (natural gypsum)	6.36E-04	2.89E-05	1.11E-05	0.00E+00	1.20E-06	6.77E-04
	Heavy spar (BaSO4)	7.98E-05	1.06E-08	2.04E-08	0.00E+00	5.63E-06	8.54E-05
	Ilmenite (titanium ore)	5.75E-07	1.31E-07	3.21E-08	0.00E+00	6.43E-09	7.44E-07
	Inert rock	6.86E-01	3.43E+00	4.82E-01	0.00E+00	5.77E-02	4.66E+00
	Iridium	3.64E-14	7.27E-14	3.49E-14	0.00E+00	3.57E-15	1.48E-13
	Iron	3.86E-03	5.25E-04	2.67E-04	0.00E+00	8.32E-04	5.49E-03

Kaolin ore	3.48E-08	3.11E-08	1.34E-08	0.00E+00	3.84E-09	8.32E-08
Lake water	4.65E+01	2.40E+01	1.65E+01	0.00E+00	3.23E+00	9.02E+01
Lead	2.24E-02	7.47E-06	5.37E-04	0.00E+00	2.51E-07	2.29E-02
Limestone (calcium carbonate)	4.53E-02	1.21E-01	6.43E-03	0.00E+00	9.70E-03	1.83E-01
Magnesit (Magnesium carbonate)	4.60E-05	1.18E-05	3.11E-06	0.00E+00	4.99E-07	6.14E-05
Magnesium	4.45E-07	1.62E-06	7.43E-07	0.00E+00	6.71E-08	2.88E-06
Magnesium chloride leach (40%)	4.23E-03	1.45E-04	7.79E-05	0.00E+00	8.49E-06	4.47E-03
Manganese	5.21E-05	9.24E-06	4.85E-06	0.00E+00	3.58E-07	6.65E-05
Manganese ore	-3.09E-11	-6.74E-12	-4.76E-12	0.00E+00	-3.27E-12	-4.57E-11
Mercury	7.67E-17	1.74E-16	5.64E-17	0.00E+00	1.44E-17	3.21E-16
Molybdenum	1.61E-07	2.14E-07	1.10E-07	0.00E+00	1.20E-08	4.96E-07
Natural Aggregate	3.18E-03	3.34E-02	2.24E-03	0.00E+00	1.34E-04	3.89E-02
Natural pumice	1.28E-05	3.03E-07	1.71E-07	0.00E+00	1.65E-08	1.33E-05
Nickel	9.52E-08	2.41E-07	1.13E-07	0.00E+00	1.08E-08	4.60E-07
Nitrogen	2.42E-12	5.48E-12	1.78E-12	0.00E+00	4.53E-13	1.01E-11
Olivine	6.50E-16	6.65E-16	2.49E-16	0.00E+00	8.96E-17	1.65E-15
Ore mined	9.67E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.67E+00
Osmium	4.44E-14	8.87E-14	4.26E-14	0.00E+00	4.35E-15	1.80E-13
Oxygen	6.57E-03	4.84E-04	7.66E-05	0.00E+00	2.97E-06	7.14E-03
Palladium	6.44E-13	1.29E-12	6.18E-13	0.00E+00	6.32E-14	2.61E-12
Perlite (Rhyolithe)	0.00E+00	2.23E-04	1.87E-06	0.00E+00	0.00E+00	2.25E-04
Phosphate ore	5.19E-05	8.91E-04	4.14E-04	0.00E+00	-2.03E-05	1.34E-03
Phosphorus	2.20E-05	1.85E-06	1.01E-06	0.00E+00	-2.49E-06	2.23E-05
Platinum	1.09E-12	2.18E-12	1.05E-12	0.00E+00	1.07E-13	4.43E-12
Potashsalt. crude (hard salt. 10% K2O)	8.21E-04	1.44E-03	7.20E-04	0.00E+00	3.90E-06	2.98E-03
Potassium chloride	6.37E-13	3.79E-13	1.66E-13	0.00E+00	7.71E-14	1.26E-12
Primary forest	9.85E-13	2.23E-12	7.24E-13	0.00E+00	1.84E-13	4.12E-12
Pyrite	5.18E-05	5.94E-08	2.12E-03	0.00E+00	2.78E-06	2.18E-03
Quartz sand (silica sand; silicon dioxide)	4.75E-03	2.12E-02	1.13E-03	0.00E+00	1.42E-04	2.73E-02
Rain water	5.22E+00	3.84E+00	1.50E+00	0.00E+00	5.11E-01	1.11E+01
Rhodium	1.09E-13	2.18E-13	1.05E-13	0.00E+00	1.07E-14	4.43E-13
River water	4.33E+02	4.33E+02	2.06E+02	0.00E+00	1.00E+02	1.17E+03
Ruthenium	2.15E-13	4.30E-13	2.07E-13	0.00E+00	2.11E-14	8.74E-13
Sea water	7.61E-01	5.02E-01	7.22E-01	0.00E+00	1.02E-01	2.09E+00
Shale	1.08E-04	1.78E-06	1.02E-06	0.00E+00	9.19E-08	1.11E-04
Silicon	4.92E-07	1.79E-06	8.21E-07	0.00E+00	7.41E-08	3.18E-06
Silver	8.62E-08	2.41E-08	4.51E-06	0.00E+00	1.52E-09	4.62E-06
Sodium chloride (rock salt)	3.46E-02	6.30E-04	3.70E-03	0.00E+00	9.90E-03	4.88E-02
Sodium nitrate	1.49E-26	2.50E-26	8.07E-27	0.00E+00	1.95E-27	5.00E-26
Sodium sulphate	1.77E-13	3.89E-14	2.73E-14	0.00E+00	1.87E-14	2.62E-13
Soil	1.25E-02	2.63E-02	2.95E-03	0.00E+00	9.57E-04	4.28E-02
Stone from mountains	1.24E-03	2.27E-05	1.33E-04	0.00E+00	3.57E-04	1.76E-03
Sulphur	1.08E-05	4.16E-05	1.74E-05	0.00E+00	1.66E-06	7.14E-05
Sulphur (bonded)	1.14E-09	5.53E-10	6.32E-06	0.00E+00	7.11E-13	6.33E-06
Talc	2.85E-09	1.10E-09	5.17E-10	0.00E+00	5.44E-11	4.52E-09
Tantalum	2.59E-10	5.60E-10	2.67E-10	0.00E+00	2.64E-11	1.11E-09
Tin	6.55E-19	1.58E-19	1.00E-19	0.00E+00	7.08E-20	9.83E-19
Tin ore (0.01%)	5.55E-08	2.45E-07	2.22E-03	0.00E+00	9.90E-09	2.22E-03
Titanium	9.26E-09	8.91E-09	4.25E-09	0.00E+00	1.10E-09	2.35E-08
Titanium ore	2.42E-07	4.72E-09	2.01E-09	0.00E+00	2.13E-08	2.70E-07

	Vanadium	7.55E-09	1.71E-08	5.55E-09	0.00E+00	1.41E-09	3.16E-08
	Zinc	8.66E-02	1.54E-05	1.09E-03	0.00E+00	9.97E-07	8.77E-02
	Zirconium	1.57E-14	7.10E-14	3.01E-14	0.00E+00	2.86E-15	1.20E-13
Outputs							
Stockpile goods [kg]	Hazardous waste (deposited)	5.06E-09	8.63E-09	2.80E-09	0.00E+00	6.85E-10	1.72E-08
	Overburden (deposited)	1.59E+00	3.46E+00	6.79E-01	0.00E+00	5.94E-02	5.78E+00
	Slag (deposited)	1.85E-12	8.42E-12	3.57E-12	0.00E+00	3.39E-13	1.42E-11
	Spoil (deposited)	2.98E-03	1.18E-02	2.55E-03	0.00E+00	1.84E-04	1.75E-02
	Tailings (deposited)	3.92E+00	8.71E-03	7.01E-02	0.00E+00	5.54E-04	4.00E+00
	Waste (deposited)	7.78E+00	3.25E-01	6.85E-03	0.00E+00	6.39E-04	8.11E+00
Radioactive waste [kg]	High radioactive waste	2.87E-07	3.44E-07	1.78E-07	0.00E+00	2.90E-08	8.38E-07
	Low radioactive wastes	4.82E-06	5.76E-06	3.00E-06	0.00E+00	3.93E-07	1.40E-05
	Medium radioactive wastes	2.66E-06	2.97E-06	1.57E-06	0.00E+00	1.92E-07	7.39E-06
	Radioactive tailings	2.11E-04	2.71E-04	1.39E-04	0.00E+00	1.98E-05	6.41E-04
Inorganic emissions to air [kg]	Aluminium	6.87E-10	3.12E-09	1.32E-09	0.00E+00	1.26E-10	5.26E-09
	Ammonia	2.28E-05	8.37E-06	5.31E-06	0.00E+00	5.71E-06	4.22E-05
	Ammonium	1.99E-10	2.62E-10	1.33E-10	1.04E-07	1.46E-11	1.05E-07
	Ammonium nitrate	3.09E-17	6.96E-18	4.82E-18	0.00E+00	3.29E-18	4.60E-17
	Argon	1.29E-07	5.43E-07	2.32E-07	0.00E+00	2.22E-08	9.26E-07
	Barium	4.86E-08	4.36E-08	1.80E-07	0.00E+00	2.67E-09	2.75E-07
	Beryllium	4.06E-10	2.96E-10	1.72E-09	0.00E+00	1.23E-11	2.43E-09
	Boron	1.79E-14	6.63E-14	4.01E-11	0.00E+00	7.27E-16	4.02E-11
	Boron compounds (unspecified)	1.39E-07	4.12E-07	2.23E-07	0.00E+00	2.26E-08	7.96E-07
	Bromine	3.19E-08	8.58E-08	6.21E-08	0.00E+00	4.80E-09	1.85E-07
	Carbon dioxide	2.32E-01	5.17E-01	3.11E-01	6.61E-01	1.55E-02	1.74E+00
	Carbon dioxide (aviation)	1.25E-06	4.50E-06	1.97E-06	0.00E+00	1.89E-07	7.91E-06
	Carbon dioxide (biotic)	1.80E-02	4.28E-02	1.98E-02	0.00E+00	2.21E-03	8.28E-02
	Carbon dioxide (land use change)	1.77E-04	5.29E-04	2.08E-04	0.00E+00	2.78E-05	9.42E-04
	Carbon dioxide (peat oxidation)	1.27E-08	1.34E-08	6.13E-09	0.00E+00	3.64E-10	3.26E-08
	Carbon disulphide	4.93E-17	1.12E-16	3.62E-17	0.00E+00	9.23E-18	2.06E-16
	Carbon monoxide	4.54E-04	4.94E-04	5.31E-04	2.76E-04	1.58E-05	1.77E-03
	Chloride (unspecified)	8.17E-08	9.06E-08	2.25E-08	0.00E+00	2.11E-08	2.16E-07
	Chlorine	1.10E-07	3.53E-08	4.41E-07	0.00E+00	4.28E-08	6.29E-07
	Cyanide (unspecified)	2.16E-08	8.15E-08	7.54E-10	0.00E+00	1.31E-10	1.04E-07
	Fluoride	4.65E-08	6.87E-08	3.65E-08	0.00E+00	4.24E-09	1.56E-07
	Fluorine	6.74E-11	1.09E-10	5.22E-11	0.00E+00	7.13E-12	2.36E-10
	Helium	1.66E-11	6.48E-11	2.76E-11	0.00E+00	2.79E-12	1.12E-10
	Hydrochloric acid	0.00E+00	0.00E+00	0.00E+00	1.61E-06	0.00E+00	1.61E-06
	Hydrogen	1.13E-05	5.62E-06	6.91E-06	0.00E+00	4.29E-05	6.67E-05
	Hydrogen bromide (hydrobromic acid)	1.04E-12	1.99E-12	9.85E-13	0.00E+00	1.14E-13	4.13E-12
	Hydrogen chloride	8.26E-06	1.09E-05	6.43E-06	0.00E+00	6.13E-07	2.62E-05
	Hydrogen cyanide (prussic acid)	7.75E-11	3.86E-09	5.10E-11	0.00E+00	3.46E-12	4.00E-09
	Hydrogen fluoride	3.85E-07	5.04E-07	2.95E-07	7.52E-07	2.92E-08	1.97E-06
	Hydrogen iodide	7.62E-20	1.72E-19	5.60E-20	0.00E+00	1.43E-20	3.19E-19
	Hydrogen phosphorous	9.51E-13	2.97E-12	1.41E-12	0.00E+00	1.29E-13	5.46E-12
	Hydrogen sulphide	9.46E-06	1.86E-05	1.03E-05	0.00E+00	9.38E-07	3.93E-05
	Lead dioxide	1.95E-15	2.59E-15	1.33E-15	0.00E+00	1.46E-16	6.02E-15

	Nitrogen (atmospheric nitrogen)	2.32E-03	1.59E-04	2.64E-05	0.00E+00	4.43E-06	2.51E-03
	Nitrogen (N-compounds)	3.00E-12	1.26E-11	5.41E-12	0.00E+00	5.15E-13	2.16E-11
	Nitrogen dioxide	3.02E-07	4.02E-05	4.78E-07	1.29E-06	1.03E-08	4.23E-05
	Nitrogen monoxide	3.26E-06	1.53E-04	1.65E-06	0.00E+00	1.11E-07	1.58E-04
	Nitrogen oxides	1.58E-03	2.45E-03	2.18E-03	3.96E-04	3.04E-05	6.64E-03
	Nitrogen. total	1.51E-12	2.54E-11	1.29E-11	0.00E+00	1.55E-13	4.00E-11
	Nitrogentriflouride	2.45E-12	7.67E-12	3.40E-12	0.00E+00	3.35E-13	1.38E-11
	Nitrous oxide (laughing gas)	3.95E-05	1.69E-05	1.04E-05	9.13E-08	4.25E-07	6.73E-05
	Oxygen	3.37E-03	3.74E-03	1.93E-03	0.00E+00	1.89E-04	9.22E-03
	Phosphorus-pent-oxide	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.66E-08	2.66E-08
	Silicium tetrafluoride	4.45E-13	1.40E-12	6.18E-13	0.00E+00	6.20E-14	2.53E-12
	Strontium	7.52E-16	2.02E-16	1.27E-16	0.00E+00	8.12E-17	1.16E-15
	Sulphur	2.40E-10	4.08E-10	2.18E-10	0.00E+00	2.77E-11	8.94E-10
	Sulphur dioxide	6.64E-04	1.70E-03	1.47E-03	5.52E-03	2.71E-05	9.38E-03
	Sulphur hexafluoride	4.05E-14	8.93E-15	6.26E-15	0.00E+00	4.29E-15	6.00E-14
	Sulphur trioxide	1.01E-07	5.02E-08	2.56E-07	0.00E+00	2.01E-09	4.09E-07
	Sulphuric acid	4.56E-09	4.96E-10	6.43E-08	0.00E+00	9.78E-12	6.94E-08
	Tin oxide	2.81E-21	6.37E-21	2.07E-21	0.00E+00	5.27E-22	1.18E-20
	Water (evapotranspiration)	4.37E+00	3.69E+00	1.55E+00	0.00E+00	1.48E-01	9.76E+00
	Water vapour	6.18E+00	1.20E+00	7.23E-01	0.00E+00	9.43E+00	1.75E+01
	Zinc chloride	1.16E-24	1.10E-24	5.13E-25	0.00E+00	7.53E-26	2.86E-24
	Zinc oxide	5.63E-21	1.27E-20	4.14E-21	0.00E+00	1.05E-21	2.35E-20
	Zinc sulphate	1.78E-09	1.41E-10	2.52E-08	0.00E+00	1.55E-12	2.71E-08
Organic emissions to air [kg]	1.1.1-Trichloroethane	8.50E-20	1.42E-19	4.57E-20	0.00E+00	1.11E-20	2.84E-19
	1.3.5-Trimethylbenzene	7.61E-14	1.93E-12	8.70E-14	0.00E+00	6.41E-15	2.10E-12
	1-Butylene (Vinylacetylene)	4.40E-12	1.12E-10	5.03E-12	0.00E+00	3.71E-13	1.21E-10
	1-Methoxy-2-propanol	1.30E-12	1.96E-11	1.02E-11	0.00E+00	4.17E-14	3.12E-11
	1-Pentene	1.56E-11	3.96E-10	1.78E-11	0.00E+00	1.31E-12	4.31E-10
	1-Tetradecane	1.14E-15	2.90E-14	1.31E-15	0.00E+00	9.65E-17	3.16E-14
	1-Tridecane	3.55E-15	9.02E-14	4.06E-15	0.00E+00	3.00E-16	9.81E-14
	1-Undecane	1.67E-15	4.23E-14	1.90E-15	0.00E+00	1.40E-16	4.60E-14
	2.2.4-Trimethylpentane	2.83E-12	7.19E-11	3.24E-12	0.00E+00	2.39E-13	7.82E-11
	2.2-Dimethylbutane	3.00E-12	7.62E-11	3.43E-12	0.00E+00	2.53E-13	8.29E-11
	2.4-Dimethylpentane	1.18E-12	2.99E-11	1.35E-12	0.00E+00	9.93E-14	3.25E-11
	2-Methyl-1-butene	1.13E-11	2.86E-10	1.29E-11	0.00E+00	9.51E-13	3.11E-10
	2-Methylpentane	2.04E-11	5.18E-10	2.33E-11	0.00E+00	1.72E-12	5.64E-10
	3-Methylpentane	1.02E-11	2.60E-10	1.17E-11	0.00E+00	8.62E-13	2.82E-10
	Acenaphthene	1.25E-11	3.51E-11	1.38E-11	0.00E+00	4.21E-13	6.19E-11
	Acenaphthylene	2.47E-11	6.92E-11	2.73E-11	0.00E+00	8.30E-13	1.22E-10
	Acetaldehyde (Ethanal)	9.17E-09	4.28E-08	2.11E-08	0.00E+00	6.60E-10	7.37E-08
	Acetic acid	7.96E-08	3.04E-07	1.87E-07	0.00E+00	7.49E-09	5.78E-07
	Acetone (dimethylcetone)	8.81E-09	4.17E-08	2.03E-08	0.00E+00	5.96E-09	7.67E-08
	Acrolein	2.26E-11	6.18E-11	2.46E-11	0.00E+00	8.92E-13	1.10E-10
	Acrylonitrile	1.28E-14	2.90E-14	9.53E-15	0.00E+00	2.39E-15	5.37E-14
	Aldehyde (unspecified)	1.87E-09	2.12E-09	1.12E-09	0.00E+00	1.38E-10	5.24E-09
	Alkane (unspecified)	3.70E-07	6.34E-07	6.71E-07	0.00E+00	3.00E-08	1.70E-06
	Alkene (unspecified)	3.36E-07	4.74E-07	5.94E-07	0.00E+00	2.79E-08	1.43E-06
	Anthracene	3.51E-12	9.60E-12	3.82E-12	0.00E+00	1.37E-13	1.71E-11

Benzene	2.85E-07	5.49E-07	3.19E-07	0.00E+00	1.92E-08	1.17E-06
Benzo{a}anthracene	1.80E-12	4.85E-12	1.93E-12	0.00E+00	7.04E-14	8.65E-12
Benzo{a}pyrene	1.57E-11	2.80E-10	3.50E-11	0.00E+00	1.31E-12	3.32E-10
Benzo{ghi}perylene	1.58E-12	4.34E-12	1.73E-12	0.00E+00	6.17E-14	7.71E-12
Benzofluoranthene	3.16E-12	8.66E-12	3.45E-12	0.00E+00	1.23E-13	1.54E-11
Biphenyl	1.57E-15	3.98E-14	1.79E-15	0.00E+00	1.32E-16	4.33E-14
Butadiene	1.16E-18	1.61E-18	1.50E-17	0.00E+00	1.67E-19	1.80E-17
Butane	1.77E-10	4.49E-09	2.02E-10	0.00E+00	1.49E-11	4.89E-09
Butane (n-butane)	4.57E-06	7.77E-06	6.15E-06	0.00E+00	2.44E-07	1.87E-05
Butene	5.00E-10	7.70E-10	7.73E-11	0.00E+00	2.07E-11	1.37E-09
C12-14 fatty alcohol	5.04E-16	2.13E-15	9.09E-16	0.00E+00	8.66E-17	3.63E-15
Caprolactam	9.04E-13	1.95E-12	9.37E-13	0.00E+00	9.24E-14	3.88E-12
Chloromethane (methyl chloride)	2.56E-13	2.76E-13	1.17E-13	0.00E+00	1.17E-14	6.60E-13
Chrysene	4.36E-12	1.19E-11	4.75E-12	0.00E+00	1.70E-13	2.12E-11
cis-2-Pentene	1.16E-11	2.95E-10	1.33E-11	0.00E+00	9.81E-13	3.21E-10
Cumene (isopropylbenzene)	2.90E-12	1.38E-11	5.56E-12	0.00E+00	5.28E-13	2.28E-11
Cyclohexane (hexahydro benzene)	1.31E-11	9.02E-12	2.90E-11	0.00E+00	2.11E-12	5.32E-11
Cyclopentane	1.99E-12	5.05E-11	2.27E-12	0.00E+00	1.68E-13	5.49E-11
Decane	6.90E-14	1.75E-12	7.89E-14	0.00E+00	5.82E-15	1.91E-12
Dibenz(a)anthracen e	9.86E-13	2.70E-12	1.07E-12	0.00E+00	3.84E-14	4.80E-12
Dichloroethane (ethylene dichloride)	9.25E-21	2.09E-20	6.80E-21	0.00E+00	1.73E-21	3.87E-20
Dichloromethane (methylene chloride)	7.40E-14	3.35E-13	1.42E-13	0.00E+00	1.35E-14	5.64E-13
Diethylamine	4.44E-18	8.11E-18	-4.18E-18	0.00E+00	7.38E-19	9.11E-18
Dimethylamine	1.30E-14	3.88E-14	1.68E-14	0.00E+00	1.86E-15	7.05E-14
Dioxins (unspec.)	1.85E-15	6.43E-16	2.26E-16	0.00E+00	1.24E-17	2.73E-15
Dodecane	3.72E-15	9.44E-14	4.25E-15	0.00E+00	3.14E-16	1.03E-13
Ethane	1.27E-05	2.16E-05	1.78E-05	0.00E+00	6.83E-07	5.29E-05
Ethanol	1.86E-08	8.44E-08	4.11E-08	0.00E+00	1.19E-09	1.45E-07
Ethene (ethylene)	2.14E-10	9.19E-10	3.91E-10	0.00E+00	2.72E-10	1.80E-09
Ethyl benzene	3.35E-07	4.66E-07	5.90E-07	0.00E+00	3.17E-08	1.42E-06
Ethylene oxide	1.61E-15	6.81E-15	2.91E-15	0.00E+00	2.77E-16	1.16E-14
Fatty methylester	5.11E-16	2.16E-15	9.21E-16	0.00E+00	8.78E-17	3.68E-15
Fluoranthene	1.15E-11	3.15E-11	1.25E-11	0.00E+00	4.47E-13	5.59E-11
Fluorene	3.65E-11	9.99E-11	3.97E-11	0.00E+00	1.42E-12	1.78E-10
Formaldehyde (methanal)	4.38E-07	1.22E-06	9.74E-07	0.00E+00	4.66E-08	2.68E-06
Halon (1301)	1.09E-18	2.46E-18	8.01E-19	0.00E+00	2.04E-19	4.56E-18
Heptane (isomers)	1.10E-07	1.11E-07	6.42E-08	0.00E+00	2.42E-09	2.87E-07
Hexamethylene diamine (HMDA)	1.55E-20	3.51E-20	1.14E-20	0.00E+00	2.90E-21	6.49E-20
Hexane (isomers)	2.04E-07	2.59E-07	1.23E-07	0.00E+00	9.71E-09	5.97E-07
HFC (unspec.)	1.96E-18	2.65E-19	1.02E-19	0.00E+00	1.53E-20	2.34E-18
Hydrocarbons (unspecified)	1.36E-05	3.44E-05	5.92E-07	0.00E+00	5.91E-08	4.87E-05
Hydrocarbons. aromatic	3.51E-09	1.66E-08	8.10E-09	0.00E+00	2.23E-10	2.85E-08
Hydrocarbons. chloro-/fluoro-	1.70E-13	5.40E-13	2.35E-13	0.00E+00	2.44E-14	9.69E-13
Hydrocarbons. halogenated	4.80E-14	1.08E-13	3.52E-14	0.00E+00	8.97E-15	2.00E-13
Indeno[1.2.3-cd]pyrene	1.18E-12	3.23E-12	1.29E-12	0.00E+00	4.59E-14	5.74E-12
iso-Butane	5.79E-11	1.47E-09	6.69E-11	0.00E+00	4.88E-12	1.60E-09
iso-Pentane	2.28E-10	5.79E-09	2.61E-10	0.00E+00	1.92E-11	6.29E-09
Isopropanol	7.86E-10	2.92E-09	1.26E-09	0.00E+00	1.25E-10	5.09E-09

Mercaptan (unspecified)	2.60E-11	9.39E-11	3.88E-11	0.00E+00	1.11E-09	1.27E-09
meta-Cresol	8.50E-14	2.61E-13	1.14E-13	0.00E+00	1.21E-14	4.72E-13
Methacrylate	1.89E-14	8.51E-14	3.61E-14	0.00E+00	3.43E-15	1.43E-13
Methane	4.82E-04	1.05E-03	6.00E-04	2.43E-07	2.99E-05	2.17E-03
Methane (biotic)	1.23E-05	3.68E-05	1.83E-05	0.00E+00	3.40E-06	7.08E-05
Methanol	1.79E-05	8.54E-08	4.61E-08	0.00E+00	1.34E-09	1.80E-05
Methyl bromide	6.32E-17	1.43E-16	4.64E-17	0.00E+00	1.18E-17	2.64E-16
Methyl cyclopentane	4.06E-12	1.03E-10	4.64E-12	0.00E+00	3.42E-13	1.12E-10
Methyl methacrylate (MMA)	2.96E-12	1.29E-11	5.48E-12	0.00E+00	5.27E-13	2.19E-11
Methyl tert-butylether	1.14E-11	2.90E-10	1.31E-11	0.00E+00	9.65E-13	3.16E-10
Naphthalene	4.57E-10	1.07E-09	5.49E-10	0.00E+00	2.02E-11	2.10E-09
n-Butyl acetate	2.50E-19	4.17E-19	1.34E-19	0.00E+00	3.25E-20	8.34E-19
NMVOC (unspecified)	6.40E-05	9.43E-05	7.25E-05	3.40E-05	2.23E-06	2.67E-04
Nonane	1.82E-14	4.62E-13	2.08E-14	0.00E+00	1.54E-15	5.03E-13
Octane	5.36E-08	6.09E-08	3.53E-08	0.00E+00	1.33E-09	1.51E-07
Organic chlorine compounds	2.15E-16	5.08E-17	3.42E-17	0.00E+00	2.29E-17	3.22E-16
para-Cresol	8.40E-14	2.59E-13	1.12E-13	0.00E+00	1.20E-14	4.67E-13
Pentane (n-pentane)	2.30E-06	4.51E-06	3.76E-06	0.00E+00	1.61E-07	1.07E-05
Phenanthrene	1.16E-10	3.18E-10	1.27E-10	0.00E+00	4.53E-12	5.66E-10
Phenol (hydroxy benzene)	9.03E-10	6.55E-10	1.49E-09	0.00E+00	6.22E-11	3.11E-09
Polychlorinated biphenyls (PCB unspecified)	3.31E-12	7.11E-12	2.35E-12	0.00E+00	1.25E-13	1.29E-11
Polychlorinated dibenzo-p-dioxins (2.3.7.8 - TCDD)	9.85E-15	1.18E-14	6.43E-15	0.00E+00	6.83E-16	2.87E-14
Polycyclic aromatic hydrocarbons (PAH. carcinogenic)	1.22E-08	2.09E-08	2.81E-09	0.00E+00	1.66E-10	3.61E-08
Polycyclic aromatic hydrocarbons (PAH. unspec.)	1.40E-11	2.34E-13	1.20E-13	0.00E+00	9.41E-16	1.43E-11
Propane	1.70E-05	2.39E-05	1.70E-05	0.00E+00	6.59E-07	5.85E-05
Propene (propylene)	3.79E-08	6.33E-08	6.18E-08	0.00E+00	2.77E-09	1.66E-07
Propionic acid (propane acid)	2.16E-11	5.45E-11	9.50E-13	0.00E+00	1.23E-13	7.72E-11
Propylene glycol methyl ether acetate	1.58E-10	4.86E-10	2.11E-10	0.00E+00	2.25E-11	8.77E-10
R 11 (trichlorofluoromethane)	1.75E-15	3.97E-15	1.29E-15	0.00E+00	3.28E-16	7.33E-15
R 114 (dichlorotetrafluoroethane)	2.10E-12	2.22E-12	8.24E-13	0.00E+00	2.57E-13	5.40E-12
R 116 (hexafluoroethane)	1.84E-11	6.65E-11	8.06E-11	0.00E+00	2.80E-12	1.68E-10
R 12 (dichlorodifluoromethane)	3.77E-16	8.53E-16	2.77E-16	0.00E+00	7.05E-17	1.58E-15
R 124 (chlorotetrafluoroethane)	8.18E-21	8.62E-21	7.44E-22	0.00E+00	1.55E-21	1.91E-20
R 125 (pentafluoroethane)	3.17E-11	3.81E-11	1.91E-11	0.00E+00	2.49E-12	9.14E-11
R 13 (chlorotrifluoromethane)	2.37E-16	5.35E-16	1.74E-16	0.00E+00	4.43E-17	9.90E-16
R 134a (tetrafluoroethane)	1.95E-11	2.35E-11	1.17E-11	0.00E+00	1.53E-12	5.63E-11
R 143 (trifluoroethane)	2.83E-11	3.40E-11	1.70E-11	0.00E+00	2.22E-12	8.16E-11

	R 22 (chlorodifluoromethane)	6.31E-12	7.10E-12	3.63E-12	0.00E+00	5.45E-13	1.76E-11
	R 23 (trifluoromethane)	2.17E-10	2.62E-10	1.31E-10	0.00E+00	1.71E-11	6.27E-10
	R 245fa (1.1.1.3.3-Pentafluoropropane)	5.63E-10	6.77E-10	3.39E-10	0.00E+00	4.42E-11	1.62E-09
	R 32 (difluoromethane)	4.75E-12	5.72E-12	2.86E-12	0.00E+00	3.73E-13	1.37E-11
	Styrene	7.34E-10	5.05E-10	1.24E-09	0.00E+00	4.95E-11	2.53E-09
	Tetrachloroethene (perchloroethylene)	5.29E-20	5.57E-20	4.81E-21	0.00E+00	9.99E-21	1.23E-19
	Tetrafluoromethane	1.60E-10	5.74E-10	6.81E-10	0.00E+00	2.45E-11	1.44E-09
	Toluene (methyl benzene)	1.58E-07	2.17E-07	2.71E-07	0.00E+00	3.65E-08	6.82E-07
	trans-2-Butene	8.80E-12	2.23E-10	1.01E-11	0.00E+00	7.42E-13	2.43E-10
	trans-2-Pentene	2.18E-11	5.53E-10	2.49E-11	0.00E+00	1.84E-12	6.02E-10
	Trichloroethene (isomers)	2.05E-11	6.55E-11	2.91E-11	0.00E+00	2.81E-12	1.18E-10
	Vinyl chloride (VCM; chloroethene)	5.03E-12	2.07E-11	8.69E-12	0.00E+00	1.15E-09	1.18E-09
	Xylene (dimethyl benzene)	1.71E-06	2.02E-06	2.47E-06	0.00E+00	1.20E-07	6.32E-06
	Xylene (meta-Xylene; 1.3-Dimethylbenzene)	2.96E-12	7.53E-11	3.39E-12	0.00E+00	2.50E-13	8.19E-11
	Xylene (ortho-Xylene; 1.2-Dimethylbenzene)	2.88E-13	7.31E-12	3.29E-13	0.00E+00	2.43E-14	7.96E-12
Heavy metals to air [kg]	Antimony	8.68E-10	1.15E-09	1.34E-08	1.13E-07	7.07E-11	1.29E-07
	Arsenic	6.77E-12	3.38E-08	2.82E-10	2.39E-07	3.45E-16	2.73E-07
	Arsenic (+V)	4.82E-09	8.47E-09	1.25E-08	0.00E+00	3.18E-10	2.61E-08
	Arsenic trioxide	1.01E-12	8.00E-14	1.42E-11	0.00E+00	8.84E-16	1.53E-11
	Cadmium	8.78E-08	5.19E-09	1.52E-09	7.68E-08	4.57E-11	1.71E-07
	Chromium	1.35E-08	6.24E-09	2.61E-08	0.00E+00	3.12E-10	4.62E-08
	Chromium (+III)	5.56E-10	3.42E-11	8.84E-11	0.00E+00	1.40E-12	6.81E-10
	Chromium (+VI)	4.99E-16	1.76E-15	9.75E-14	0.00E+00	6.90E-17	9.99E-14
	Cobalt	2.01E-09	1.88E-09	8.76E-09	0.00E+00	8.05E-11	1.27E-08
	Copper	5.03E-08	7.49E-08	2.38E-08	5.69E-07	4.84E-10	7.19E-07
	Heavy metals to air (unspecified)	3.34E-10	3.67E-10	1.88E-10	0.00E+00	2.19E-11	9.12E-10
	Hydrogen arsenic (arsine)	8.35E-11	6.64E-12	1.18E-09	0.00E+00	7.34E-14	1.27E-09
	Iron	2.43E-07	4.09E-08	2.05E-08	0.00E+00	1.51E-09	3.06E-07
	Lanthanum	3.87E-17	1.04E-17	6.52E-18	0.00E+00	4.18E-18	5.98E-17
	Lead	1.25E-06	1.21E-07	1.02E-07	6.48E-06	2.17E-09	7.95E-06
	Manganese	4.17E-07	9.32E-08	3.52E-07	0.00E+00	3.78E-09	8.65E-07
	Mercury	4.31E-06	9.76E-09	1.70E-08	6.32E-08	6.56E-10	4.40E-06
	Molybdenum	4.72E-10	3.36E-10	2.45E-10	0.00E+00	2.03E-11	1.07E-09
	Nickel	8.51E-09	2.33E-08	5.06E-08	0.00E+00	5.43E-10	8.30E-08
	Palladium	2.08E-17	4.59E-18	3.22E-18	0.00E+00	2.21E-18	3.09E-17
	Rhodium	2.01E-17	4.43E-18	3.11E-18	0.00E+00	2.13E-18	2.98E-17
	Scandium	1.98E-17	5.25E-18	3.32E-18	0.00E+00	2.14E-18	3.05E-17
	Selenium	1.10E-08	2.75E-08	1.82E-08	9.28E-08	1.34E-09	1.51E-07
	Silver	6.87E-10	3.12E-09	1.32E-09	0.00E+00	1.26E-10	5.26E-09
	Tellurium	7.37E-11	2.83E-12	1.08E-12	2.75E-08	1.17E-13	2.76E-08
	Thallium	2.86E-10	1.93E-11	8.80E-12	0.00E+00	7.43E-13	3.14E-10
	Tin	9.04E-09	1.58E-08	1.78E-07	1.45E-09	8.25E-10	2.05E-07
	Titanium	4.74E-09	7.02E-10	3.52E-10	0.00E+00	2.57E-11	5.82E-09
	Vanadium	2.51E-08	4.10E-08	5.99E-08	0.00E+00	1.24E-09	1.27E-07
	Zinc	1.81E-06	1.56E-07	1.29E-07	2.81E-06	3.09E-09	4.91E-06
Heavy metals to	Arsenic (+V)	3.24E-13	9.98E-17	5.12E-17	0.00E+00	7.95E-18	3.24E-13
	Cadmium	2.85E-09	2.36E-09	1.01E-09	0.00E+00	1.01E-10	6.32E-09

agricultural soil [kg]	Chromium	-2.75E-09	-9.07E-09	-3.81E-09	0.00E+00	-3.33E-10	-1.60E-08
	Chromium (+III)	3.98E-09	5.26E-09	2.16E-09	0.00E+00	3.53E-10	1.17E-08
	Cobalt	3.24E-13	9.98E-17	5.12E-17	0.00E+00	7.95E-18	3.24E-13
	Copper	-1.72E-08	-5.77E-08	-2.41E-08	0.00E+00	-2.02E-09	-1.01E-07
	Iron	3.61E-10	1.11E-13	5.71E-14	0.00E+00	8.87E-15	3.62E-10
	Lead	1.07E-10	-1.74E-08	-7.46E-09	0.00E+00	-4.39E-10	-2.52E-08
	Manganese	2.38E-11	7.33E-15	3.76E-15	0.00E+00	5.84E-16	2.38E-11
	Mercury	3.98E-11	5.26E-11	2.16E-11	0.00E+00	3.53E-12	1.17E-10
	Molybdenum	1.94E-12	5.98E-16	3.07E-16	0.00E+00	4.77E-17	1.94E-12
	Nickel	-8.29E-10	-7.57E-09	-3.23E-09	0.00E+00	-1.99E-10	-1.18E-08
	Tin	5.19E-10	1.60E-13	8.20E-14	0.00E+00	1.27E-14	5.19E-10
	Vanadium	1.94E-12	5.98E-16	3.07E-16	0.00E+00	4.77E-17	1.94E-12
	Zinc	-8.77E-08	-2.02E-07	-8.46E-08	0.00E+00	-6.88E-09	-3.81E-07
Inorganic emissions to agricultural soil [kg]	Aluminium	1.99E-09	6.14E-13	3.15E-13	0.00E+00	4.89E-14	1.99E-09
	Chlorine	8.40E-10	2.59E-13	1.33E-13	0.00E+00	2.06E-14	8.41E-10
	Sulphur	4.35E-10	1.34E-13	6.87E-14	0.00E+00	1.07E-14	4.35E-10
Particles to air [kg]	Aluminium oxide (dust)	2.41E-15	2.99E-15	2.38E-17	0.00E+00	2.22E-16	5.65E-15
	Dust (> PM10)	1.40E-05	1.04E-04	4.79E-05	7.17E-05	1.85E-06	2.39E-04
	Dust (PM10)	7.57E-08	1.14E-06	2.16E-08	0.00E+00	1.03E-08	1.24E-06
	Dust (PM2.5 - PM10)	1.82E-05	8.67E-05	1.23E-05	0.00E+00	1.44E-06	1.19E-04
	Dust (PM2.5)	6.46E-05	1.57E-04	6.31E-05	0.00E+00	1.61E-06	2.86E-04
	Dust (unspecified)	4.06E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.06E-07
	Metals (unspecified)	9.07E-11	3.49E-10	1.51E-10	0.00E+00	1.45E-11	6.05E-10
	Silicon dioxide (silica)	6.47E-11	2.94E-10	1.24E-10	0.00E+00	1.18E-11	4.95E-10
Pesticides to air [kg]	Pesticides to air	1.36E-08	5.32E-09	2.27E-09	0.00E+00	2.13E-10	2.14E-08
Other emissions to air [kg]	Other emissions to air	7.43E-01	6.84E+00	2.34E+00	0.00E+00	8.65E-02	1.00E+01
Radioactive emissions to air [kg]	Radioactive emissions to air	9.84E-15	6.80E-15	2.92E-15	0.00E+00	1.21E-15	2.08E-14
Inorganic emissions to fresh water [kg]	Acid (calculated as H+)	2.06E-09	8.57E-09	1.06E-08	0.00E+00	3.53E-10	2.16E-08
	Aluminium	7.15E-07	1.09E-06	4.79E-07	0.00E+00	6.83E-08	2.36E-06
	Ammonia	4.05E-07	7.86E-06	2.89E-07	0.00E+00	3.25E-08	8.59E-06
	Ammonium (total N)	2.06E-13	8.51E-14	8.55E-14	0.00E+00	4.46E-15	3.81E-13
	Ammonium / ammonia	8.18E-06	1.51E-06	1.67E-06	0.00E+00	8.94E-07	1.23E-05
	Barium	9.29E-07	1.43E-06	3.23E-07	0.00E+00	2.02E-08	2.70E-06
	Beryllium	2.72E-11	3.50E-11	1.80E-11	0.00E+00	2.56E-12	8.27E-11
	Boron	2.72E-05	6.86E-07	3.19E-07	0.00E+00	7.35E-08	2.83E-05
	Bromate	2.19E-19	4.95E-19	1.61E-19	0.00E+00	4.10E-20	9.16E-19
	Bromine	6.06E-16	2.18E-15	9.15E-16	0.00E+00	9.03E-17	3.79E-15
	Calcium	1.26E-03	1.76E-04	3.93E-04	0.00E+00	1.27E-04	1.96E-03
	Carbon disulphide	3.01E-05	3.33E-11	1.41E-11	0.00E+00	1.34E-12	3.01E-05
	Carbonate	6.14E-05	8.99E-05	2.04E-05	0.00E+00	8.73E-07	1.72E-04
	Chlorate	1.11E-14	2.51E-14	8.14E-15	0.00E+00	2.07E-15	4.64E-14
	Chloride	6.63E-03	9.17E-03	3.00E-03	0.00E+00	4.92E-04	1.93E-02
	Chlorine	1.78E-05	4.69E-12	1.99E-12	0.00E+00	1.89E-13	1.78E-05
	Chlorine (dissolved)	1.11E-06	1.25E-06	1.79E-06	0.00E+00	9.15E-08	4.24E-06
	Cyanide	9.48E-09	4.71E-08	7.65E-10	0.00E+00	1.53E-10	5.75E-08
	Fluoride	4.73E-05	2.36E-04	8.56E-05	0.00E+00	1.01E-05	3.79E-04

	Fluorine	1.77E-08	8.63E-10	1.50E-07	0.00E+00	1.11E-11	1.69E-07
	Hydrogen chloride	3.87E-08	1.23E-09	5.06E-10	0.00E+00	3.39E-09	4.39E-08
	Hydrogen cyanide (prussic acid)	8.09E-17	3.65E-16	1.55E-16	0.00E+00	1.47E-17	6.15E-16
	Hydrogen fluoride (hydrofluoric acid)	1.52E-09	1.53E-08	3.02E-10	0.00E+00	3.81E-11	1.71E-08
	Hydrogen peroxide	1.13E-07	3.27E-07	1.38E-07	0.00E+00	1.69E-08	5.95E-07
	Hydroxide	8.89E-11	3.63E-10	1.57E-10	0.00E+00	1.46E-11	6.23E-10
	Inorganic salts and acids (unspecified)	1.08E-22	2.44E-22	7.92E-23	0.00E+00	2.02E-23	4.51E-22
	Iodide	5.26E-17	1.19E-16	3.87E-17	0.00E+00	9.85E-18	2.20E-16
	Magnesium	5.33E-05	2.10E-05	9.77E-06	0.00E+00	9.35E-07	8.50E-05
	Magnesium chloride	2.95E-10	1.32E-09	5.57E-10	0.00E+00	5.35E-11	2.22E-09
	Metal ions (unspecific)	1.43E-08	3.21E-09	1.54E-09	0.00E+00	1.52E-10	1.92E-08
	Nitrate	3.68E-05	5.89E-05	2.10E-05	0.00E+00	3.28E-06	1.20E-04
	Nitrite	2.44E-09	9.83E-10	1.00E-09	0.00E+00	5.19E-11	4.48E-09
	Nitrogen	3.31E-08	4.01E-08	2.05E-08	0.00E+00	-2.87E-09	9.08E-08
	Nitrogen (as total N)	2.55E-09	3.28E-09	1.69E-09	0.00E+00	2.40E-10	7.76E-09
	Nitrogen organic bound	1.73E-05	9.65E-06	3.61E-06	0.00E+00	5.13E-07	3.11E-05
	Nitrogen oxides	2.09E-09	9.70E-13	4.14E-13	0.00E+00	3.95E-14	2.09E-09
	Phosphate	4.12E-06	2.26E-06	8.90E-07	0.00E+00	9.08E-08	7.36E-06
	Phosphorus	2.48E-07	3.46E-07	9.08E-08	0.00E+00	2.94E-07	9.78E-07
	Potassium	3.36E-05	8.83E-07	2.51E-07	0.00E+00	-1.83E-08	3.47E-05
	Silicate particles	1.31E-11	5.93E-11	2.51E-11	0.00E+00	2.39E-12	9.98E-11
	Sodium	5.78E-04	2.00E-04	2.43E-04	0.00E+00	8.03E-05	1.10E-03
	Sodium chloride (rock salt)	5.37E-08	1.01E-07	4.31E-08	0.00E+00	4.11E-09	2.02E-07
	Sodium hypochlorite	5.99E-07	6.64E-07	1.38E-07	0.00E+00	3.92E-07	1.79E-06
	Sodium sulphate	3.57E-06	7.52E-06	3.27E-06	0.00E+00	4.06E-07	1.48E-05
	Strontium	1.11E-07	1.08E-06	1.36E-07	0.00E+00	9.78E-09	1.34E-06
	Sulfate	2.22E-03	6.21E-04	2.07E-04	0.00E+00	1.06E-03	4.11E-03
	Sulphide	1.06E-05	1.64E-05	3.70E-06	0.00E+00	2.36E-07	3.10E-05
	Sulphite	5.00E-08	2.07E-07	9.66E-08	0.00E+00	9.20E-09	3.63E-07
	Sulphur	8.14E-13	1.76E-12	2.12E-10	0.00E+00	1.45E-13	2.15E-10
	Sulphur trioxide	5.94E-10	2.46E-09	1.13E-09	0.00E+00	8.21E-11	4.26E-09
	Sulphuric acid	1.12E-10	5.07E-10	2.15E-10	0.00E+00	2.04E-11	8.55E-10
Organic emissions to fresh water [kg]	1.2-Dibromoethane	6.13E-25	1.02E-24	3.30E-25	0.00E+00	7.97E-26	2.05E-24
	Acenaphthene	1.66E-10	4.44E-10	1.18E-10	0.00E+00	3.46E-12	7.32E-10
	Acenaphthylene	6.86E-11	1.52E-10	3.86E-11	0.00E+00	1.45E-12	2.60E-10
	Acetic acid	4.98E-10	1.85E-09	8.28E-10	0.00E+00	7.06E-11	3.24E-09
	Acrylonitrile	4.60E-17	5.28E-17	7.42E-16	0.00E+00	6.07E-18	8.47E-16
	Alkane (unspecified)	6.88E-17	1.56E-16	5.06E-17	0.00E+00	1.29E-17	2.88E-16
	Anthracene	3.15E-10	9.02E-10	2.43E-10	0.00E+00	6.53E-12	1.47E-09
	Aromatic hydrocarbons (unspecified)	3.11E-09	8.72E-09	2.56E-09	0.00E+00	9.28E-11	1.45E-08
	Benzene	3.51E-07	5.79E-07	1.35E-07	0.00E+00	7.55E-09	1.07E-06
	Benzo{a}anthracene	1.76E-11	3.01E-11	7.08E-12	0.00E+00	3.78E-13	5.51E-11
	Benzofluoranthene	2.11E-12	3.13E-12	6.97E-13	0.00E+00	4.55E-14	5.98E-12
	Butanediol	2.72E-13	1.15E-12	4.90E-13	0.00E+00	4.67E-14	1.95E-12
	Carbon. organically bound	2.62E-04	1.41E-04	5.48E-05	0.00E+00	5.64E-06	4.64E-04
	Chlorinated hydrocarbons (unspecified)	8.17E-17	1.85E-16	6.00E-17	0.00E+00	1.53E-17	3.42E-16
	Chloromethane (methyl chloride)	2.56E-14	5.82E-15	4.01E-15	0.00E+00	2.72E-15	3.81E-14
	Chrysene	6.36E-11	9.84E-11	2.23E-11	0.00E+00	1.37E-12	1.86E-10
	Cresol (methyl phenol)	7.32E-18	1.66E-17	5.39E-18	0.00E+00	1.37E-18	3.07E-17

	Dichloroethane (ethylene dichloride)	2.06E-22	4.65E-22	1.51E-22	0.00E+00	3.85E-23	8.61E-22
	Dichloropropane	1.25E-23	2.82E-23	9.16E-24	0.00E+00	2.33E-24	5.21E-23
	Ethyl benzene	1.91E-08	3.14E-08	7.31E-09	0.00E+00	4.11E-10	5.82E-08
	Fluoranthene	3.03E-11	1.85E-10	5.48E-11	0.00E+00	5.65E-13	2.71E-10
	Formaldehyde (methanal)	3.08E-16	3.55E-16	1.78E-16	0.00E+00	3.38E-17	8.74E-16
	Hexane (isomers)	8.02E-19	1.81E-18	5.89E-19	0.00E+00	1.50E-19	3.36E-18
	Hydrocarbons (unspecified)	1.36E-08	2.20E-08	5.41E-09	0.00E+00	1.06E-09	4.20E-08
	Methanol	5.55E-06	6.73E-07	5.14E-07	0.00E+00	2.23E-08	6.76E-06
	Naphthalene	1.09E-08	1.67E-08	3.76E-09	0.00E+00	2.36E-10	3.16E-08
	Oil (unspecified)	3.26E-05	7.76E-05	1.89E-06	0.00E+00	2.18E-07	1.12E-04
	Organic chlorine compounds (unspecified)	1.99E-15	1.83E-15	7.03E-16	0.00E+00	2.66E-16	4.79E-15
	Organic compounds (dissolved)	5.31E-12	2.29E-11	9.75E-12	0.00E+00	9.28E-13	3.89E-11
	Organic compounds (unspecified)	1.12E-06	1.05E-06	2.59E-07	0.00E+00	7.49E-07	3.18E-06
	Pentachlorophenol (PCP)	1.65E-13	3.73E-13	1.21E-13	0.00E+00	3.09E-14	6.91E-13
	Phenol (hydroxy benzene)	3.59E-07	5.73E-07	1.23E-07	0.00E+00	7.84E-09	1.06E-06
	Polychlorinated dibenzo-p-dioxins (2.3.7.8 - TCDD)	6.99E-22	1.56E-22	1.09E-22	0.00E+00	7.42E-23	1.04E-21
	Polycyclic aromatic hydrocarbons (PAH. unspec.)	5.31E-11	6.34E-11	2.61E-11	0.00E+00	3.07E-12	1.46E-10
	Tetrachloroethene (perchloroethylene)	2.19E-15	4.97E-15	1.61E-15	0.00E+00	4.11E-16	9.18E-15
	Toluene (methyl benzene)	2.13E-07	3.46E-07	8.00E-08	0.00E+00	4.59E-09	6.43E-07
	Trichloromethane (chloroform)	2.19E-15	4.97E-15	1.61E-15	0.00E+00	4.11E-16	9.19E-15
	Triethylene glycol	2.89E-17	6.54E-17	2.12E-17	0.00E+00	5.41E-18	1.21E-16
	Vinyl chloride (VCM; chloroethene)	2.19E-13	9.94E-13	4.21E-13	0.00E+00	4.00E-14	1.67E-12
	Xylene (isomers; dimethyl benzene)	7.62E-08	1.26E-07	2.92E-08	0.00E+00	1.64E-09	2.33E-07
Heavy metals to fresh water [kg]	Antimony	3.21E-10	1.00E-10	4.17E-11	0.00E+00	6.98E-07	6.98E-07
	Arsenic	1.25E-08	7.63E-14	3.94E-14	0.00E+00	2.87E-07	3.00E-07
	Arsenic (+V)	1.12E-07	1.72E-07	4.42E-08	0.00E+00	3.01E-09	3.31E-07
	Cadmium	4.98E-08	7.48E-08	1.97E-08	0.00E+00	1.66E-07	3.11E-07
	Chromium	2.95E-07	2.10E-06	6.32E-07	0.00E+00	6.44E-09	3.03E-06
	Chromium (+III)	1.50E-08	9.36E-09	3.97E-09	0.00E+00	4.58E-10	2.87E-08
	Chromium (+VI)	1.13E-09	1.06E-09	2.61E-10	0.00E+00	7.53E-10	3.20E-09
	Cobalt	7.52E-11	7.06E-11	1.80E-11	0.00E+00	5.08E-11	2.15E-10
	Copper	1.10E-07	1.08E-07	3.16E-08	0.00E+00	3.03E-07	5.52E-07
	Heavy metals to water (unspecified)	1.38E-14	3.76E-15	2.34E-15	0.00E+00	1.50E-15	2.14E-14
	Iron	3.95E-05	1.25E-04	4.87E-05	0.00E+00	6.66E-06	2.19E-04
	Lead	1.48E-07	1.23E-07	5.40E-08	0.00E+00	2.46E-06	2.79E-06
	Manganese	1.60E-07	2.94E-07	6.57E-08	0.00E+00	1.05E-08	5.31E-07
	Mercury	1.60E-09	1.29E-09	1.86E-09	0.00E+00	3.38E-09	8.13E-09
	Molybdenum	2.43E-08	4.36E-08	2.25E-08	0.00E+00	2.82E-09	9.32E-08
	Nickel	1.34E-07	1.61E-07	4.03E-08	0.00E+00	1.58E-07	4.94E-07
	Selenium	5.89E-09	6.00E-09	3.10E-09	0.00E+00	4.02E-10	1.54E-08
	Silver	1.57E-10	1.52E-10	4.02E-11	0.00E+00	2.26E-10	5.75E-10
	Tantalum	8.07E-16	1.74E-15	8.33E-16	0.00E+00	8.23E-17	3.47E-15
	Thallium	3.21E-10	2.81E-12	5.00E-10	0.00E+00	3.10E-14	8.23E-10
	Tin	2.86E-11	1.25E-14	6.66E-15	0.00E+00	4.57E-09	4.59E-09
	Titanium	4.78E-09	5.91E-09	3.04E-09	0.00E+00	4.14E-10	1.41E-08

	Tungsten	4.27E-11	8.42E-11	3.03E-11	0.00E+00	6.84E-12	1.64E-10
	Vanadium	7.83E-09	8.50E-09	4.49E-09	0.00E+00	5.95E-10	2.14E-08
	Zinc	5.58E-07	6.69E-08	1.24E-07	0.00E+00	3.36E-06	4.11E-06
Analytical measures to fresh water [kg]	Adsorbable organic halogen compounds (AOX)	1.90E-07	1.47E-07	7.55E-08	0.00E+00	3.97E-08	4.52E-07
	Biological oxygen demand (BOD)	1.93E-06	2.34E-06	6.37E-07	0.00E+00	1.01E-06	5.92E-06
	Chemical oxygen demand (COD)	9.57E-05	3.05E-04	1.26E-04	0.00E+00	1.53E-05	5.42E-04
	Nitrogenous Matter (unspecified. as N)	3.56E-07	1.48E-05	1.96E-07	0.00E+00	1.28E-08	1.53E-05
	Solids (dissolved)	2.97E-03	7.48E-07	4.11E-07	0.00E+00	6.21E-08	2.97E-03
	Total dissolved organic bound carbon (TOC)	3.01E-10	1.06E-10	5.49E-11	0.00E+00	7.66E-12	4.69E-10
	Total organic bound carbon (TOC)	1.75E-06	1.20E-06	6.13E-07	0.00E+00	3.70E-08	3.60E-06
Other emissions to fresh water [kg]	Acetochlor	7.30E-20	8.20E-20	6.75E-21	0.00E+00	1.42E-20	1.76E-19
	Alachlor	5.07E-09	5.81E-09	2.46E-09	0.00E+00	2.28E-10	1.36E-08
	Aldicarb	1.20E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.20E-10
	Atrazine	1.28E-19	1.44E-19	1.18E-20	0.00E+00	2.48E-20	3.08E-19
	Benomyl	1.32E-11	1.06E-11	4.50E-12	0.00E+00	4.17E-13	2.87E-11
	Bentazone	1.00E-13	1.49E-13	3.76E-14	0.00E+00	1.56E-14	3.03E-13
	Carbofuran	2.23E-13	2.41E-13	1.19E-13	0.00E+00	1.25E-14	5.95E-13
	Chlormequat-chloride	8.54E-16	1.18E-15	5.42E-16	0.00E+00	6.43E-17	2.64E-15
	Collected rainwater to river	2.46E-02	2.76E-01	5.16E-03	0.00E+00	6.39E-04	3.06E-01
	Cooling water to river	1.14E+01	1.32E+01	5.21E+00	0.00E+00	5.77E+01	8.76E+01
	Cypermethrin	1.04E-17	1.44E-17	6.57E-18	0.00E+00	7.80E-19	3.21E-17
	Cyprodinil (CGA-219417)	2.33E-16	3.23E-16	1.48E-16	0.00E+00	1.75E-17	7.21E-16
	Deltamethrin	3.14E-14	5.33E-14	1.80E-14	0.00E+00	4.52E-15	1.07E-13
	Detergent (unspecified)	2.89E-20	6.55E-20	2.13E-20	0.00E+00	5.41E-21	1.21E-19
	Dicamba	4.89E-21	5.49E-21	4.52E-22	0.00E+00	9.47E-22	1.18E-20
	Diflufenican	5.44E-17	7.53E-17	3.45E-17	0.00E+00	4.09E-18	1.68E-16
	Dimethenamid	1.45E-20	1.63E-20	1.34E-21	0.00E+00	2.81E-21	3.49E-20
	Ethephon	2.59E-18	3.59E-18	1.64E-18	0.00E+00	1.95E-19	8.01E-18
	Fenvalerate	9.96E-16	6.08E-17	2.61E-17	0.00E+00	3.22E-18	1.09E-15
	Fipronil	4.97E-22	5.58E-22	4.60E-23	0.00E+00	9.64E-23	1.20E-21
	Glyphosate	4.88E-10	2.93E-13	7.38E-14	0.00E+00	3.05E-14	4.89E-10
	Imidacloprid	5.18E-18	7.18E-18	3.29E-18	0.00E+00	3.90E-19	1.60E-17
	Ioxynil	1.68E-16	2.33E-16	1.07E-16	0.00E+00	1.27E-17	5.21E-16
	Isoproturon	2.20E-16	3.05E-16	1.40E-16	0.00E+00	1.66E-17	6.81E-16
	Mancozeb	4.97E-11	1.82E-10	7.69E-11	0.00E+00	7.08E-12	3.16E-10
	MCPA	3.62E-16	5.02E-16	2.30E-16	0.00E+00	2.73E-17	1.12E-15
	Mecoprop	2.46E-16	3.41E-16	1.56E-16	0.00E+00	1.85E-17	7.61E-16
	Methomyl	4.69E-14	1.11E-13	4.79E-14	0.00E+00	2.40E-15	2.08E-13
	Parathion-methyl	5.69E-15	8.48E-15	2.13E-15	0.00E+00	8.84E-16	1.72E-14
	Processed water to groundwater	4.75E-01	3.58E-03	1.58E-03	0.00E+00	1.37E-04	4.80E-01
	Processed water to river	2.62E+00	9.73E-01	2.85E-01	0.00E+00	8.50E+00	1.24E+01
	Terbufos	1.20E-01	5.70E-01	1.68E-01	0.00E+00	2.20E-02	8.80E-01
	Thiram	1.20E-01	5.69E-01	1.68E-01	0.00E+00	2.20E-02	8.80E-01
	Trifluralin	1.18E-01	5.00E-01	1.48E-01	0.00E+00	2.05E-02	7.87E-01
	Turbined water to river	4.72E+02	4.45E+02	2.17E+02	0.00E+00	3.73E+01	1.17E+03
Particles to fresh water [kg]	Particles to fresh water	3.01E-03	2.12E-03	8.38E-04	0.00E+00	9.55E-05	6.06E-03

Radioactive emissions to fresh water [kg]	Radioactive emissions to fresh water	1.90E+01	2.06E+01	1.11E+01	0.00E+00	1.50E+00	5.22E+01
Inorganic emissions to sea water [kg]	Aluminium	1.65E-11	5.83E-12	4.04E-12	0.00E+00	2.49E-12	2.89E-11
	Ammonia	1.77E-15	1.83E-15	6.02E-16	0.00E+00	1.48E-16	4.35E-15
	Ammonium / ammonia	4.45E-12	1.57E-12	1.09E-12	0.00E+00	6.71E-13	7.78E-12
	Barium	2.45E-07	2.86E-07	1.61E-07	0.00E+00	5.98E-09	6.98E-07
	Beryllium	4.79E-17	1.08E-16	3.52E-17	0.00E+00	8.97E-18	2.00E-16
	Boron	4.06E-16	9.19E-16	2.99E-16	0.00E+00	7.60E-17	1.70E-15
	Calcium	8.63E-14	2.91E-13	1.13E-13	0.00E+00	1.60E-14	5.07E-13
	Carbonate	1.54E-05	1.80E-05	1.01E-05	0.00E+00	3.76E-07	4.39E-05
	Chloride	1.22E-03	1.42E-03	8.03E-04	0.00E+00	2.98E-05	3.47E-03
	Cyanide	1.97E-15	8.88E-15	3.76E-15	0.00E+00	3.58E-16	1.50E-14
	Fluoride	6.11E-10	3.14E-09	3.95E-09	0.00E+00	1.24E-10	7.82E-09
	Magnesium	6.06E-09	1.15E-08	9.40E-09	0.00E+00	2.77E-10	2.72E-08
	Nitrate	1.72E-07	7.70E-08	5.03E-08	0.00E+00	2.34E-08	3.23E-07
	Nitrate (as total N)	8.41E-17	3.82E-16	1.62E-16	0.00E+00	1.54E-17	6.43E-16
	Nitrite	2.16E-09	7.64E-10	5.29E-10	0.00E+00	3.26E-10	3.78E-09
	Nitrogen (as total N)	6.42E-16	8.68E-17	3.35E-17	0.00E+00	5.03E-18	7.67E-16
	Phosphorus	3.88E-11	1.37E-11	9.49E-12	0.00E+00	5.85E-12	6.78E-11
	Potassium	1.20E-14	5.46E-14	2.31E-14	0.00E+00	2.20E-15	9.20E-14
	Sodium	6.93E-07	1.31E-06	1.08E-06	0.00E+00	3.17E-08	3.11E-06
	Strontium	7.19E-10	1.36E-09	1.12E-09	0.00E+00	3.29E-11	3.23E-09
	Sulphate	6.50E-06	7.57E-06	4.27E-06	0.00E+00	1.59E-07	1.85E-05
	Sulphide	2.81E-06	3.27E-06	1.85E-06	0.00E+00	6.85E-08	8.00E-06
	Sulphur	4.96E-10	1.75E-10	1.21E-10	0.00E+00	7.48E-11	8.67E-10
Organic emissions to sea water [kg]	Acenaphthene	4.00E-11	4.67E-11	2.63E-11	0.00E+00	9.77E-13	1.14E-10
	Acenaphthylene	1.72E-11	2.01E-11	1.13E-11	0.00E+00	4.20E-13	4.90E-11
	Acetic acid	7.47E-17	1.69E-16	5.49E-17	0.00E+00	1.40E-17	3.13E-16
	Anthracene	7.48E-11	8.72E-11	4.92E-11	0.00E+00	1.83E-12	2.13E-10
	Aromatic hydrocarbons (unspecified)	3.47E-10	6.57E-10	5.39E-10	0.00E+00	1.59E-11	1.56E-09
	Benzene	9.20E-08	1.07E-07	6.05E-08	0.00E+00	2.25E-09	2.62E-07
	Benzo{a}anthracene	4.59E-12	5.35E-12	3.02E-12	0.00E+00	1.12E-13	1.31E-11
	Benzofluoranthene	5.59E-13	6.52E-13	3.68E-13	0.00E+00	1.37E-14	1.59E-12
	Chrysene	1.68E-11	1.96E-11	1.11E-11	0.00E+00	4.10E-13	4.79E-11
	Cresol (methyl phenol)	5.63E-18	1.27E-17	4.14E-18	0.00E+00	1.05E-18	2.36E-17
	Ethyl benzene	5.01E-09	5.84E-09	3.29E-09	0.00E+00	1.22E-10	1.43E-08
	Ethylene Glycol	3.85E-14	6.86E-15	2.72E-15	0.00E+00	3.68E-16	4.84E-14
	Fluoranthene	5.20E-12	6.06E-12	3.42E-12	0.00E+00	1.27E-13	1.48E-11
	Hexane (isomers)	6.15E-19	1.39E-18	4.52E-19	0.00E+00	1.15E-19	2.57E-18
	Hydrocarbons (unspecified)	1.06E-13	2.40E-13	7.81E-14	0.00E+00	1.99E-14	4.45E-13
	Naphthalene	2.89E-09	3.37E-09	1.90E-09	0.00E+00	7.06E-11	8.24E-09
	Oil (unspecified)	4.69E-07	5.47E-07	3.09E-07	0.00E+00	1.15E-08	1.34E-06
	Phenol (hydroxy benzene)	9.30E-08	1.08E-07	6.12E-08	0.00E+00	2.27E-09	2.65E-07
	Tetrachloroethene (perchloroethylene)	9.04E-19	2.05E-18	6.65E-19	0.00E+00	1.69E-19	3.79E-18
	Toluene (methyl benzene)	5.59E-08	6.52E-08	3.68E-08	0.00E+00	1.37E-09	1.59E-07
	Xylene (isomers; dimethyl benzene)	2.00E-08	2.33E-08	1.32E-08	0.00E+00	4.88E-10	5.69E-08
Heavy metals to sea water [kg]	Arsenic (+V)	2.81E-08	3.28E-08	1.86E-08	0.00E+00	6.88E-10	8.02E-08
	Cadmium	4.35E-08	1.40E-08	7.94E-09	0.00E+00	2.94E-10	6.57E-08
	Chromium	4.40E-08	5.13E-08	2.89E-08	0.00E+00	1.07E-09	1.25E-07
	Cobalt	6.36E-13	2.26E-13	1.56E-13	0.00E+00	9.61E-14	1.12E-12

	Copper	9.92E-09	1.30E-08	8.25E-09	0.00E+00	2.83E-10	3.14E-08
	Iron	1.59E-11	5.64E-12	3.90E-12	0.00E+00	2.40E-12	2.78E-11
	Lead	6.51E-07	1.01E-08	5.92E-09	0.00E+00	2.15E-10	6.67E-07
	Manganese	2.54E-12	9.01E-13	6.23E-13	0.00E+00	3.84E-13	4.45E-12
	Mercury	7.09E-11	8.93E-11	5.54E-11	0.00E+00	1.94E-12	2.18E-10
	Molybdenum	2.16E-18	4.88E-18	1.58E-18	0.00E+00	4.04E-19	9.02E-18
	Nickel	1.57E-08	1.86E-08	1.08E-08	0.00E+00	3.93E-10	4.55E-08
	Silver	6.40E-18	1.45E-17	4.70E-18	0.00E+00	1.20E-18	2.68E-17
	Tin	7.66E-18	1.73E-17	5.63E-18	0.00E+00	1.43E-18	3.21E-17
	Titanium	7.80E-19	1.77E-18	5.74E-19	0.00E+00	1.46E-19	3.27E-18
	Vanadium	5.77E-16	1.30E-15	4.24E-16	0.00E+00	1.08E-16	2.41E-15
	Zinc	3.55E-06	6.86E-10	5.62E-10	0.00E+00	1.78E-11	3.55E-06
Analytical measures to sea water [kg]	Adsorbable organic halogen compounds (AOX)	3.22E-14	5.95E-14	4.88E-14	0.00E+00	1.44E-15	1.42E-13
	Biological oxygen demand (BOD)	3.57E-08	6.57E-08	5.39E-08	0.00E+00	1.59E-09	1.57E-07
	Chemical oxygen demand (COD)	1.53E-06	2.04E-06	1.32E-06	0.00E+00	4.50E-08	4.93E-06
	Total organic bound carbon (TOC)	3.47E-08	6.57E-08	5.39E-08	0.00E+00	1.59E-09	1.56E-07
Other emissions to sea water [kg]	Cooling water to sea	7.52E-01	4.98E-01	7.13E-01	0.00E+00	1.01E-01	2.07E+00
	Processed water to sea	5.24E-02	1.08E-03	3.82E-03	0.00E+00	1.05E-03	5.84E-02
	Solids (suspended)	1.24E-04	5.23E-05	4.29E-05	0.00E+00	1.26E-06	2.20E-04
Heavy metals to industrial soil [kg]	Antimony	1.08E-15	1.48E-15	1.46E-14	0.00E+00	8.05E-17	1.72E-14
	Arsenic (+V)	3.78E-13	1.50E-12	1.06E-11	0.00E+00	7.96E-14	1.26E-11
	Cadmium	5.28E-11	8.08E-12	7.88E-11	0.00E+00	4.37E-13	1.40E-10
	Chromium	3.24E-13	8.09E-13	3.45E-13	0.00E+00	1.48E-13	1.63E-12
	Chromium (+III)	2.36E-13	3.20E-13	1.62E-13	0.00E+00	1.76E-14	7.35E-13
	Chromium (+VI)	1.06E-20	1.11E-20	1.70E-21	0.00E+00	1.79E-21	2.51E-20
	Cobalt	9.44E-13	1.29E-12	5.90E-11	0.00E+00	7.68E-13	6.20E-11
	Copper	6.22E-09	7.46E-12	3.64E-12	0.00E+00	7.22E-13	6.23E-09
	Iron	2.57E-09	2.25E-10	7.97E-10	0.00E+00	1.03E-11	3.60E-09
	Lead	2.66E-12	1.05E-11	7.51E-11	0.00E+00	5.40E-13	8.89E-11
	Manganese	2.77E-12	5.19E-12	1.42E-11	0.00E+00	1.28E-11	3.49E-11
	Mercury	1.29E-14	5.77E-14	1.69E-12	0.00E+00	4.17E-15	1.77E-12
	Nickel	1.06E-11	1.39E-11	8.40E-12	0.00E+00	2.62E-12	3.56E-11
	Selenium	2.74E-15	4.66E-15	9.01E-13	0.00E+00	1.91E-16	9.09E-13
	Zinc	2.09E-06	1.63E-11	1.18E-11	0.00E+00	5.55E-12	2.09E-06
Inorganic emissions to industrial soil [kg]	Aluminium	6.34E-12	2.57E-11	3.44E-11	0.00E+00	1.08E-12	6.75E-11
	Ammonia	1.10E-08	9.64E-09	3.89E-09	0.00E+00	4.02E-07	4.27E-07
	Beryllium	6.16E-18	2.28E-17	1.38E-14	0.00E+00	2.51E-19	1.39E-14
	Bromide	1.31E-14	4.20E-14	1.68E-14	0.00E+00	1.87E-15	7.38E-14
	Calcium	1.86E-08	7.75E-09	3.28E-09	0.00E+00	3.48E-07	3.78E-07
	Chloride	2.10E-06	1.64E-06	8.34E-07	0.00E+00	3.35E-07	4.90E-06
	Chlorine	9.89E-13	1.33E-12	6.71E-13	0.00E+00	7.23E-14	3.06E-12
	Fluoride	2.30E-09	1.80E-09	9.16E-10	0.00E+00	3.47E-09	8.48E-09
	Magnesium	2.15E-10	8.16E-10	3.41E-10	0.00E+00	3.46E-08	3.60E-08
	Nitric acid	2.94E-08	7.75E-15	3.28E-15	0.00E+00	3.12E-16	2.94E-08
	Nitrogen	4.89E-14	2.22E-13	9.40E-14	0.00E+00	8.94E-15	3.74E-13
	Phosphorus	2.34E-10	7.56E-10	3.03E-10	0.00E+00	2.21E-07	2.22E-07
	Potassium	5.44E-10	1.93E-09	7.91E-10	0.00E+00	6.83E-08	7.16E-08
	Sodium	1.03E-09	1.66E-09	6.83E-10	0.00E+00	1.57E-08	1.90E-08
	Strontium	6.93E-14	1.57E-13	5.09E-14	0.00E+00	1.29E-14	2.90E-13
	Sulphate	9.45E-09	2.05E-10	8.60E-11	0.00E+00	1.34E-08	2.32E-08
	Sulphide	3.14E-10	1.23E-09	5.16E-10	0.00E+00	8.06E-08	8.26E-08
	Sulphur	1.01E-10	2.28E-10	7.40E-11	0.00E+00	1.88E-11	4.21E-10
	Acetic acid	6.31E-11	8.40E-11	4.31E-11	0.00E+00	4.72E-12	1.95E-10

Organic emissions to industrial soil [kg]	Hydrocarbons (unspecified)	4.38E-07	1.16E-13	4.90E-14	0.00E+00	4.65E-15	4.38E-07
	Methanol	4.51E-12	6.00E-12	3.08E-12	0.00E+00	3.37E-13	1.39E-11
	Oil (unspecified)	1.22E-11	4.48E-11	5.16E-11	0.00E+00	1.81E-12	1.10E-10

Annex C: Additional Results

Toxicity

A toxicity analysis was conducted to determine which stages and emissions are the greatest contributors to each USEtox™ indicator. The precision of the current USEtox™[4] characterization factors is within a factor of 100–1,000 for human health and 10–100 for freshwater ecotoxicity (Rosenbaum et al 2008). Given this limitation, results are reported only as relative values and should not be used to support comparative assertions.

Figure C 1 shows all ecotoxicity results separated by process stage.

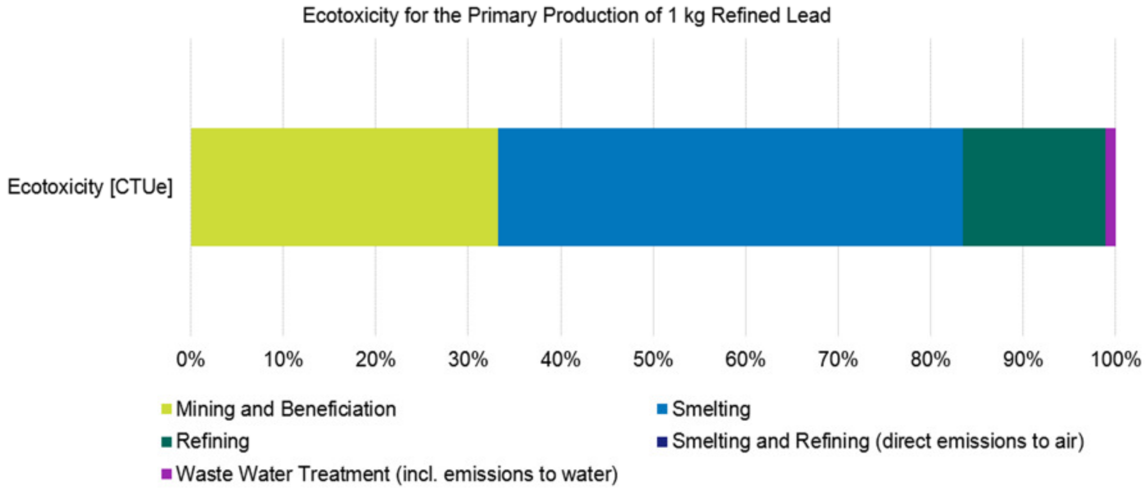

Figure C-1: Relative ecotoxicity results for primary production mix of 1 kg refined lead

The smelting stage contributes over 50% to total ecotoxicity for the primary production mix of refined lead, while mining and beneficiation is approximately 33%. The primary drivers of burdens are the emissions of alachlor and phenol to fresh water, contributing 37% and 35%, respectively.

[4] The USEtox recommended toxicity impact categories have been used in this assessment. Metal emissions have been excluded, since the characterization factors for metals are available as part of the current version of USEtox, are all considered "interim", since they have much higher uncertainty than the recommended characterization factors.

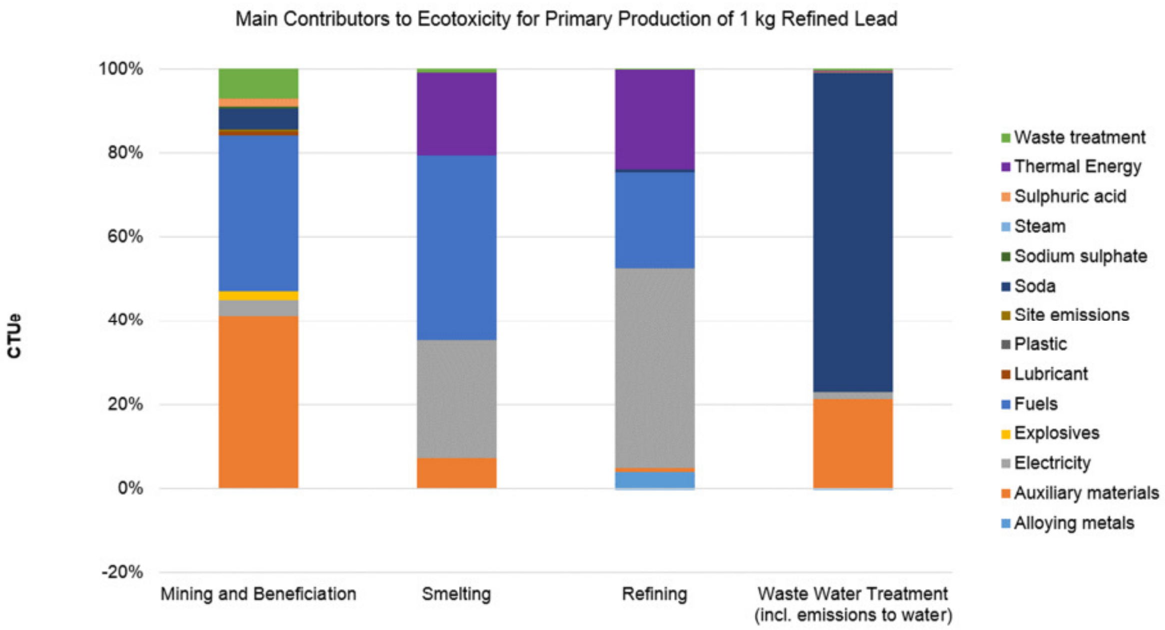

Figure C-2: Main contributors to the Ecotoxicity for the primary production mix of 1 kg refined lead

Figure C-3 shows human toxicity (cancerous) results separated by process stage.

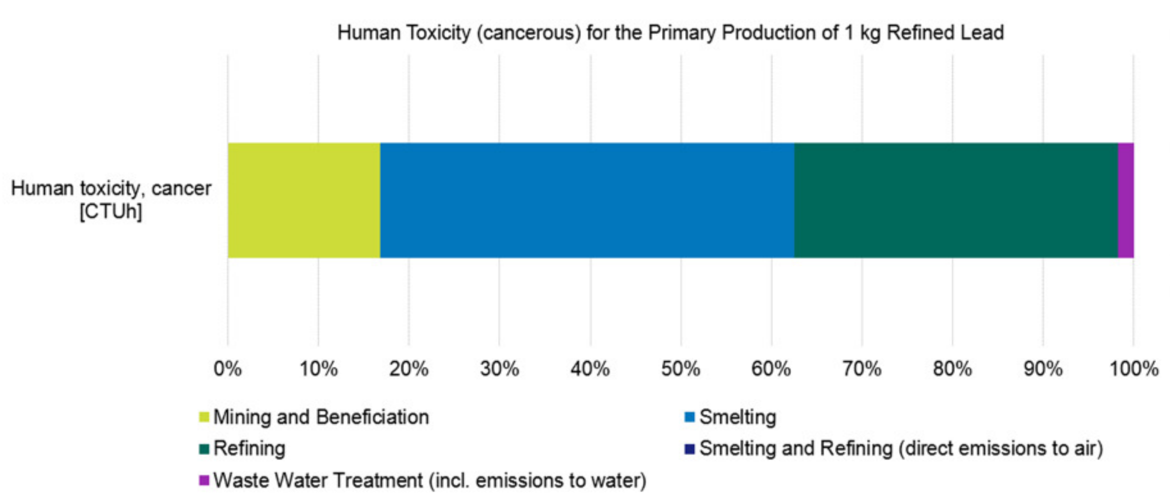

Figure C-3: Human toxicity (cancerous) for the primary production mix of 1 kg refined lead

The smelting and refining dominate the impact, contributing 46% and 36% of human toxicity (cancerous) results. The main contributing emission to air is formaldehyde with 95% from the production of soda.

Figure C-4 shows the main contributors to human toxicity (cancerous) for the primary production mix of 1 kg refined lead.

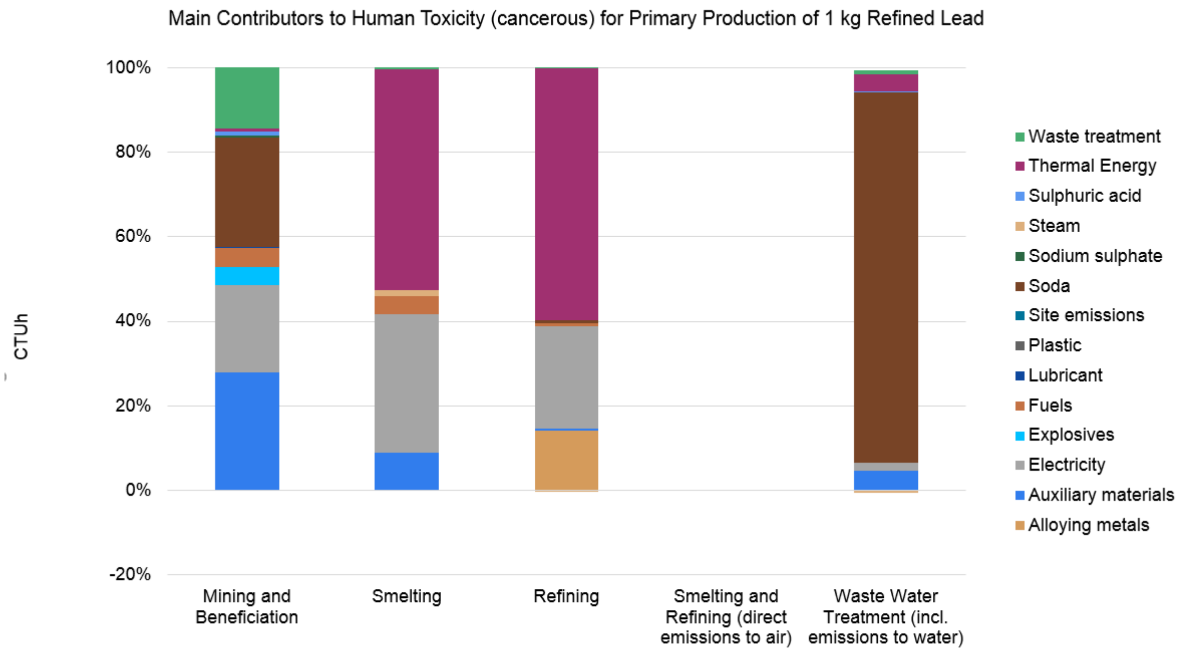

Figure C-4: Main contributors to the Human toxicity (cancerous) for the primary production mix of 1 kg refined lead

Figure C-5 shows human toxicity (non-cancerous) results separated by process stage.

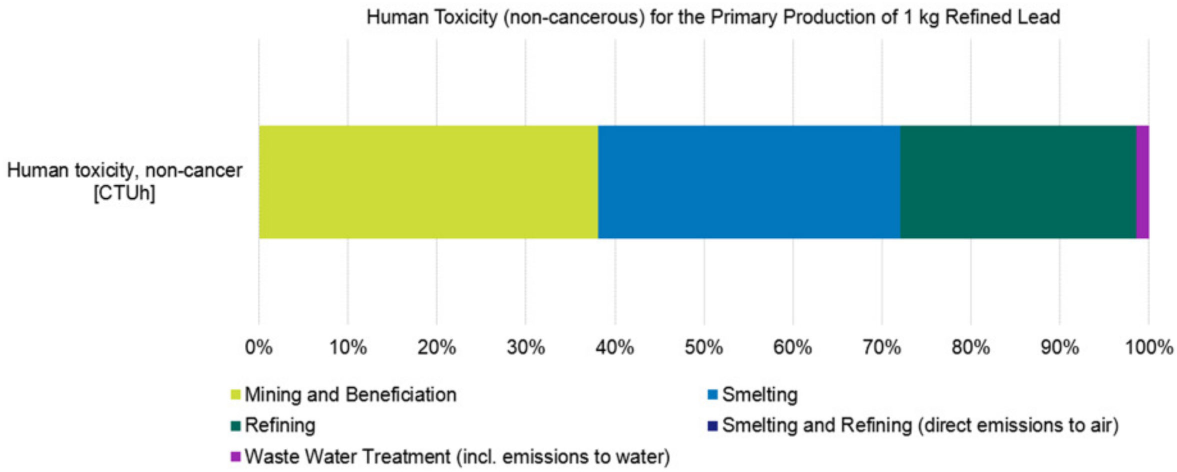

Figure C-5: Human toxicity (non-cancerous) for the primary production mix of 1 kg refined lead

The mining and beneficiation stage contribute 38% to total human toxicity (non-cancerous) for the primary production mix of refined lead, while smelting contributes 34%. The primary drivers of burden are emissions of xylene and formaldehyde to air, contributing 33% and 22%, respectively.

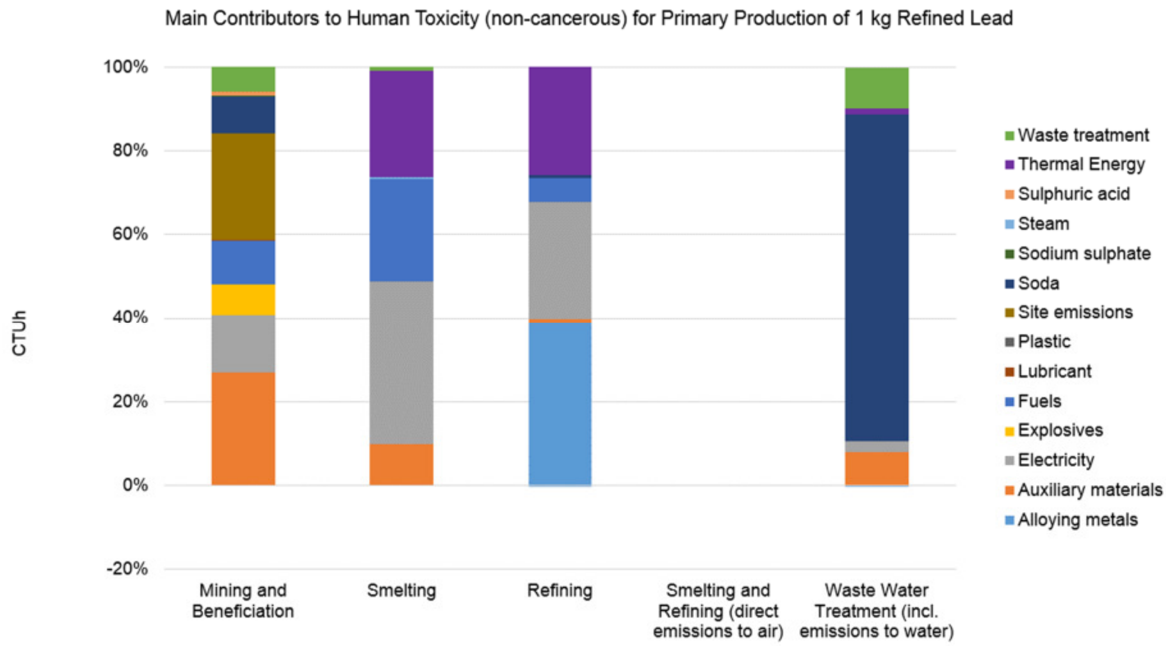

Figure C-6 shows the main contributors to human toxicity (non-cancerous) for the primary production mix of 1 kg refined lead. Smelting is mainly driven by the upstream production of electricity, fuels, and thermal energy.

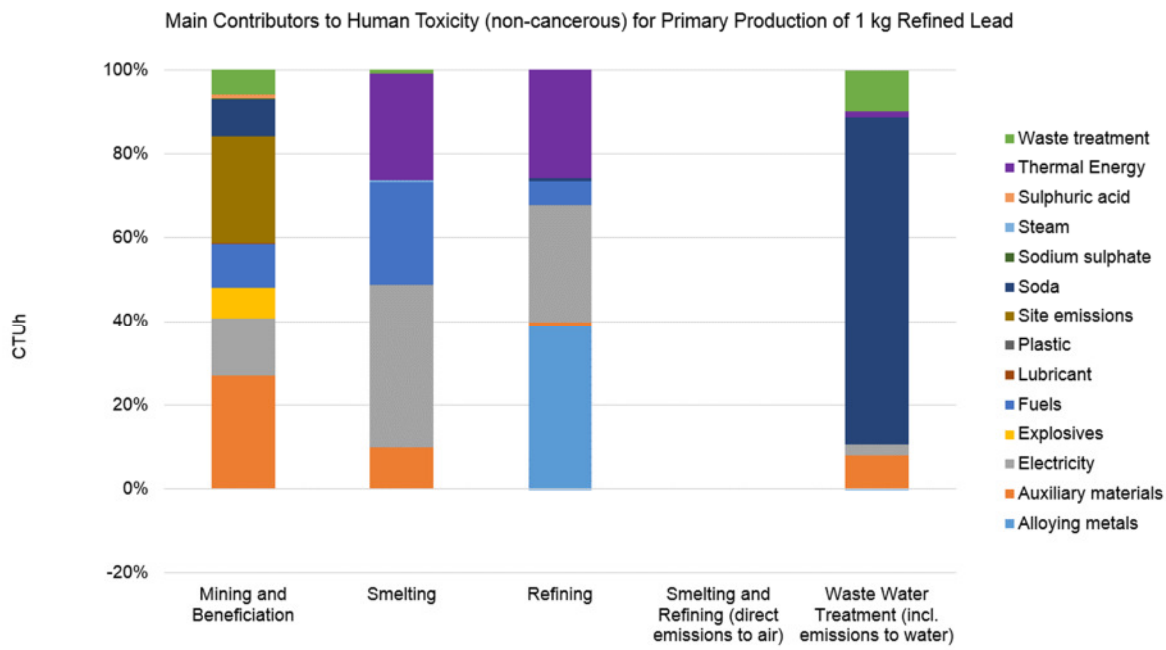

Figure C-6: Main contributors to the Human toxicity (non-cancerous) for the primary production mix of 1 kg refined lead

Particulate Matter

Fine particulate matter (PM) is a widespread air pollutant consisting of solid and liquid particles suspended in the air. Particles can either be directly emitted into the air (primary PM) or be formed in the atmosphere from gaseous precursors such as sulphur dioxide, oxides of nitrogen, ammonia and non-methane volatile organic compounds (secondary particles). PM_{10} (particles with a diameter of less than 10 µm) and $PM_{2.5}$ (particles with a diameter of less than 2.5 µm) include inhalable particles that are small enough to penetrate the thoracic region of the respiratory system. The health effects of inhalable PM are well documented and include respiratory and cardiovascular morbidity, such as aggravation of asthma, respiratory symptoms and an increase in hospital admissions, as well as mortality from cardiovascular and respiratory diseases and from lung cancer.

This impact category measures the risk to human health associated with particulate matter and selected inorganic emissions resulting from a product system. For the primary route, Figure C-7 and Figure C-8 shows all particulate matter results, separated by each production stage, the smelting step accounts for 30% of the total particulate matter impact for the primary production mix of lead, while direct site emissions contribute 40%. Though less significant a contributor, the mining and beneficiation process contributes about 12% of the total particulate matter impact. The main emissions to air contributing to this impact category is Dust (PM2.5) with 74% followed by sulphur dioxide (24%).

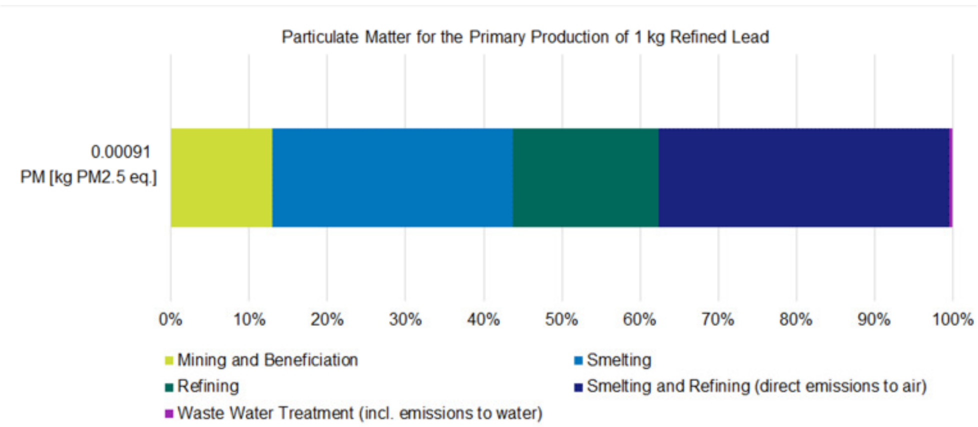

Figure C-7: Relative particulate matter results, by product stage, primary route

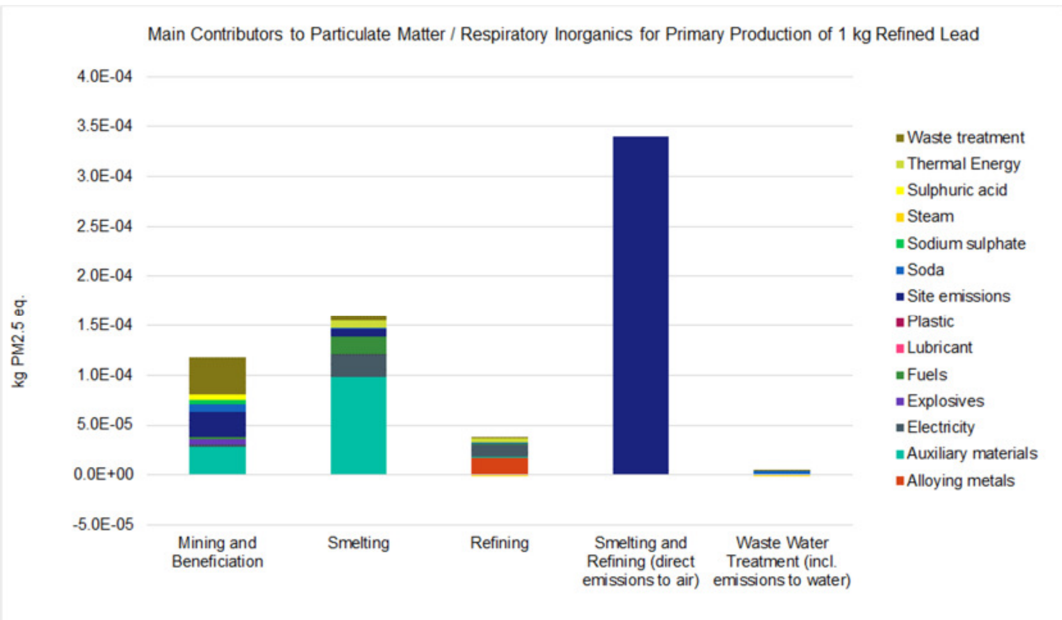

Figure C-8: Main contributors to the particulate matter for the primary production mix of 1 kg refined lead

Land Use

Land transformation considers the extent of changes in land properties and the area affected. Figure C-9 shows the land use change results, separated by production stage. The smelting processes and mining and beneficiation contribute 47% and 28% respectively to land use change, with the majority of these impacts coming from inbound transport of lead-containing materials, electricity, and soda production.

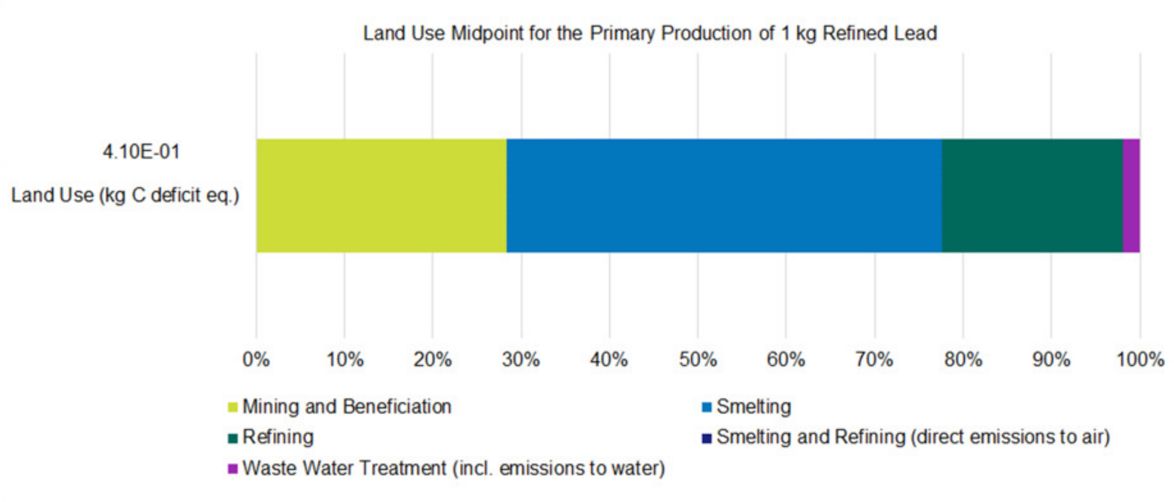

Figure C-9: Relative land use change results, by product stage, primary production mix

Figure C-10 shows the land use change results broken down by specific activities across all processing steps. Electricity, overall, contributes the most to the total life cycle land use change impacts, followed by the auxiliary materials specifically related to the mining and beneficiation stage.

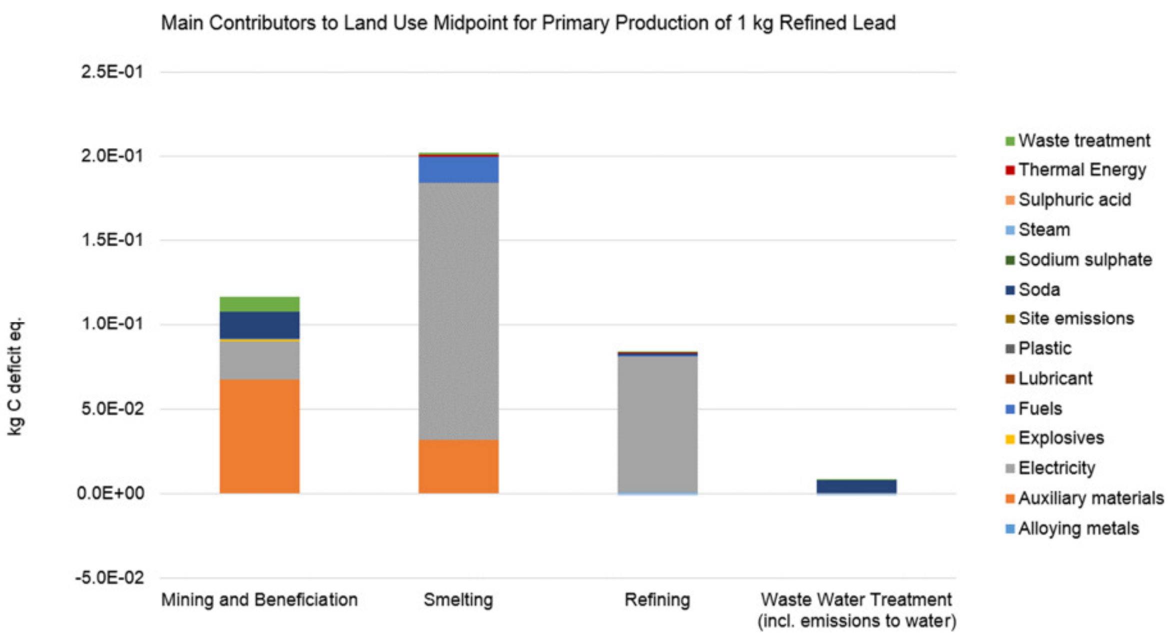

Figure C-10: Main contributors to the land use change for the primary production mix of 1 kg refined lead